SURVEY REPORT
FOR
FLOOD CONTROL
ANDROSCOGGIN RIVER
MAINE AND NEW HAMPSHIRE

AUTHORIZED BY THE
FLOOD CONTROL ACT
APPROVED JUNE 22, 1936.

U.S. ENGINEER OFFICE
BOSTON, MASS.
JUNE 30, 1938.

July 28, 1938
R&H File No. 4867/8

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Subject: Survey Report for Flood Control - Androscoggin River, Maine and New Hampshire.

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Office, Division Engineer, NORTH ATLANTIC DIVISION, New York City, July 22, 1938 - To the Chief of Engineers, U. S. Army

I concur in the recommendation of the District Engineer that no improvement of the Androscoggin River for flood control be made by the Federal Government.

/s/ E. L. DALEY
Colonel, Corps of Engineers,
Division Engineer.

Incl. accpg:
2/3.18a (17 copies);
List of interested parties. (in quad.)

SURVEY REPORT FOR FLOOD CONTROL

ANDROSCOGGIN RIVER, MAINE AND NEW HAMPSHIRE

JUNE 30, 1938

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REPORT ON A SURVEY OF THE ANDROSCOGGIN RIVER, MAINE AND NEW HAMPSHIRE, FOR FLOOD CONTROL

Syllabus

The District Engineer finds that the average annual flood damages in the Androscoggin Basin are about $453,400. These damages are caused principally by severe floods of rather infrequent occurrence. The most practicable means of obtaining comprehensive flood control throughout the basin is by means of reservoirs. Existing power storage in the Rangeley Lake System already provides a high degree of control, with appreciable flood-reducing effects, of 31.6% of the basin area. Additional control of 42.5% of the basin area, bringing the total control to 74.1% of the total basin, could be provided with a system of four reservoirs which would eliminate 82.5% of the average annual flood damages.

The District Engineer concludes that the four reservoirs, or any combination thereof, would not be economically justified at the present time. There are possibilities for multiple-purpose development of the reservoirs for flood control, conservation storage and power generation, but these are also not justified at the present time.

The District Engineer also concludes that local flood protection by means of levees and river walls or channel improvements is not warranted at the present time. Many local flood problems could be alleviated by the reconstruction or removal, at the end of their economic or physical life, of dams, bridges and buildings which affect flood flows and by the provision of zoning regulations to eliminate channel encroachments and developments in areas subject to frequent flooding.

The District Engineer recommends that no improvement of the Androscoggin River for flood control by means of new construction be undertaken at the present time and that all agencies concerned cooperate in improvement of the flood situation by coordination of existing storage, flood-warning and forecasting services and zoning regulations.

War Department
U. S. Engineer Office
Boston, Massachusetts

June 30, 1938

Subject: Report on a Survey of the Androscoggin River, Maine and New Hampshire, for Flood Control.

To: The Division Engineer, North Atlantic Division, New York, N.Y.

I. INTRODUCTION

1. Authority. - This report is submitted in accordance with an Act (Public No. 812, 74th Congress) approved June 25, 1936, authorizing a "preliminary examination of the Androscoggin River, in Maine and New Hampshire, and its tributaries, with a view to control of their floods" and the Flood Control Act (Public No. 738, 74th Congress) approved June 22, 1936, which reads in part as follows:

> "Section 6. The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control at the following-named localities * * * * * * Androscoggin River, Maine * * * * * *."

A preliminary examination report dated October 11, 1937 was submitted by the District Engineer and reviewed by the Division Engineer and the Board of Engineers for Rivers and Harbors. A survey to determine the extent and character of flood protection which is economically justified was authorized on January 24, 1938 (E.D.7402(Androscoggin River, Me.)-16).

2. Scope of the Survey. - This report is based on field surveys and studies undertaken after the floods of March, 1936. The field work included: levels to determine the high-water profile of the March, 1936 flood; a comprehensive survey of direct and indirect damages to determine the incremental amount of losses suffered at increasing stages of the flood in separate reaches of the river; aerial photographic surveys of 27 localities covering key damage centers or prospective reservoir sites; geological reconnaissance of 25 prospective reservoir sites; detailed topographical surveys of four selected reservoir sites. The office studies included: a determination of the most unfavorable meteorological and ground conditions by the U. S. Weather Bureau in cooperation with the

Engineer Department; collection and study of meteorological and hydrological data from twelve precipitation observation stations in or near the watershed, eleven stream gaging stations and other sources; preliminary investigations and estimates of cost for 25 prospective dams and reservoirs; detailed analysis for four dams and reservoirs and the analysis of local flood protection possibilities at 11 flood damage centers. These data, together with the previous reports of this department and pertinent work of other agencies, were studied as outlined in this report with a view to determination of the extent and character of flood protection which is economically justified.

3. Prior Reports. - There are two prior reports on this river pertaining in whole or in part to flood control:

a. A report under the provisions of House Document No. 308, 69th Congress, 1st Session, covering navigation, flood control, power development and irrigation. This report, printed as House Document 646, 71st Congress, 3d Session, concluded that conditions were not favorable at that time (1930) for coordinated river development.

b. A preliminary examination report dated October 11, 1937 which concluded that general flood protection for the basin could be most practicably secured by means of reservoir control, but that the annual flood damages in the basin are not sufficient to warrant complete flood protection at the present time. A survey was recommended to determine the extent and character of the partial flood protection which may be justified in the basin.

4. Reports of Other Agencies. - Extensive reference was made during this survey to all reports, publications and other data of Federal, State, municipal and private organizations which contain information on the Androscoggin River. The most important of these sources

of information are cited throughout the report in the sections to which they apply. Acknowledgment is due to all agencies and individuals who cooperated in procuring and furnishing data for this survey and especially to those whose efforts during and immediately following the floods of March, 1936 made possible the collection of vital information which would not otherwise have been available to the Engineer Department.

5. Existing Project. - There are no prior or existing projects for flood control for the Androscoggin River.

6. Maps. - The United States Geological Survey general maps of Maine and New Hampshire (scale 1:500,000, or about 8 miles to 1 inch), and Sheet 1 of the New Hampshire Transportation Map and Sheets 2 and 6 of the Maine Transportation Map (scale 1:250,000, or about 4 miles to 1 inch) issued by the Bureau of Public Roads, include the basin. The Geological Survey topographic sheets (scale 1:62,500, or about 1 mile to 1 inch) cover about 85 per cent of the area. Some details of the tidal portion of the river are shown on United States Coast and Geodetic Survey Charts Nos. 314 and 1204, but these contain no soundings above the outlet into Merrymeeting Bay. The United States Geological Survey has issued a profile of the main river from tidewater to Umbagog Lake (scale 1:24,000 horizontal and 20 feet to 1 inch vertical) with maps of the upper portion beginning at a point about 10 miles below Rumford, Maine. The survey for these maps and profile was made in 1905.

II. DESCRIPTION OF THE BASIN

7. Location and General Description. - The watershed of the Androscoggin River lies principally in western Maine, with part of the headwater area, comprising 20 per cent of the total, lying in New Hampshire (see Figures 1 and 2). The basin has a length of 110 miles, maximum width of 55 miles and a total area of 3,470 square miles. The lake and pond area of 143 square miles, 4.1 per cent of the total area, exercises complete or partial control over approximately 1400 square miles, or 40 per cent of the entire basin. The general elevation of the watershed is higher than that of any other eastern river in the United States. The upper portions are rough, mountainous and almost entirely covered by forests. The lower portions are hilly, partly wooded and contain considerable cultivated land.

8. Geology and Topography. - The lower portion of the basin is characterized by broad, low hills and long, gentle slopes with prevalent large lake and swamp areas. The upper portion of the basin is dominated by irregular groups of steep hills and low mountains, with numerous lakes and marshes in the intervening lowlands. The lowlands and much of the hill topography constitute the haphazard, little dissected, surface of the deep glacial overburden beneath which the preglacial bedrock drainage courses are completely buried. Across the lowest areas of this overburden the Androscoggin River and its tributaries follow irregular winding courses in poorly-defined valleys. Development of tributary drainage is still rudimentary. While bedrock is exposed, or close to the surface, in the high hills and mountains, outcrops are small and scattered in the lowlands. Bedrock is exposed in numerous short channel reaches, but, with few exceptions, the channel has not been incised into the rock more than 5 to 10 feet. Bedrock within the drainage area is predominantly granite, schist and gneiss with occasional areas of slate and other metamorphic rocks.

The overburden consists mainly of gravelly, somewhat silty sands. Extensive deposits of sand and, in some areas, silt, are found in the lowlands.

9. Description of the Main Stream. - The river rises at the Canadian border near the boundary between the States of Maine and New Hampshire in mountainous territory which lies at an elevation of 2600 to 2900 feet above mean sea level. The main river is considered as having its source in Umbagog Lake but the actual headwaters of the principal contributing streams lie about 40 miles further north. From Umbagog Lake the river flows in a southerly direction in New Hampshire for about 35 miles before turning east into Maine. From the Maine-New Hampshire line the river continues in an easterly direction for a distance of 70 miles and then turns to flow generally south for 60 miles before reaching tidewater at Brunswick, Maine. The mouth of the river is at its outlet into the west end of Merrymeeting Bay, a tidal basin through the eastern portion of which the Kennebec River flows. The total length of the Androscoggin River from headwater to tidewater is about 200 miles. Umbagog Lake lies at an elevation of 1244 feet above mean sea level, giving an average slope of the river in the 167 miles from Umbagog Lake to tidewater of nearly 7.5 feet per mile. In the 30 miles from Umbagog Lake to a point just above Berlin, New Hampshire, there is a fall of 152 feet, or 5.1 feet per mile. In the next 2.7 miles there is concentrated a fall of 238 feet, or slightly more than 88 feet per mile. From this point to the state line, a distance of 35 miles, the fall is 174 feet, or 5.0 feet per mile. The fall from the state line to the mouth of Swift River at Rumford, a distance of 37 miles, is 258 feet, or 7.0 feet per mile, but included in this reach is a fall of 177 feet in a distance of 1.7 miles at Rumford, more than 100 feet per mile. In the next 21 miles there is a fall of only 68 feet, or 3.2 feet to the mile, and in the remaining 61 miles to tidewater, 354 feet,

or nearly 6 feet to the mile. A profile is shown on Figure 29. Records of discharge of the main river at Auburn, Maine (drainage area 3260 square miles), 24 miles above Brunswick, for the 9-year period 1928-1936 give: maximum 135,000 cubic feet per second (March 20, 1936); minimum 465 cubic feet per second; mean 5420 cubic feet per second. The tidal portion of the river extends from Merrymeeting Bay to the natural falls and dam at Brunswick, a distance of about 3 miles. The mean range of tide in this reach varies from 3 to 5 feet and the controlling depth at mean low water is 3 feet or less.

10. Description of Tributaries. - The principal tributaries of the Androscoggin River are given in the following table in order of location from headwater to mouth. A profile showing the Webb, Nezinscot, and Little Androscoggin Rivers is shown on Figure 30.

TABLE 1. TRIBUTARIES OF THE ANDROSCOGGIN RIVER

River	Drainage Area (sq.mi.)	Location		Distance of mouth from tidewater (miles)	Discharge of Record (c.f.s./sq.mi.)		
		Headwaters	Mouth		Max.	Min.	Mean
Magalloway	500	At International boundary 13 Mi.W. of Big Island, Me.	Errol, N.H.	165	Completely Regulated		
Swift	135	5 Mi.N. of Houghton, Me.	Rumford, Me.	82	136.84	.05*	1.87
Webb	125	3 Mi.N.E. of Weld, Me.	Dixfield, Me.	75	No gaging station		
Dead	100	4 Mi. N. of Vienna, Me.	5 Mi. N. of Leeds, Me.	46	No gaging station		
Nezinscot	275	2 Mi. N.W.of Redding, Me.	4 Mi. N.E. of Turner, Me.	38	No gaging station		
Little Androscoggin	380	Bryant Pond, Me.	Auburn, Me.	24	46.58	.01*	1.83

* Regulated by controlled storage.

11. <u>Population</u>. - The total population of the basin in 1930 was nearly 150,000; approximately 124,000 in Maine and 26,000 in New Hampshire. The upper part of the basin is largely wild land with comparatively few settlements, almost all of which are on, or close to, the streams. In the lower half of the basin there is a large volume of manufacturing, the principal products being cotton goods, pulp and paper. The only cities and towns in the basin with populations exceeding 4,000 are the following (all located on the main river):

TABLE 2. PRINCIPAL CITIES AND TOWNS

City or Town	Population (1930 Census)	Distance from Tidewater (miles)
Lewiston, Me.	34,948	24
Auburn, Me.	18,571	24
Berlin, N. H.	20,018	134
Rumford, Me.	10,340	82
Brunswick, Me.	7,604	0
Mexico, Me.	4,767	82
Lisbon, Me	4,002	7

12. <u>Transportation</u>. - In general the highway system for the Androscoggin Basin is adequate for present requirements, comprising a trunk-highway system with connecting roads in the central and lower valley and sufficient roads in the northern portion of the basin to provide access to the lakes and small settlements in this section. The principal railroads are the Maine Central and the Grand Trunk, serving the southern portion of the basin. Railroads serving the northern section have been replaced by bus lines. The river is regarded as navigable to Brunswick at the head of tidewater, but there have been no improvements for navigation and there is no record of appreciable commercial or pleasure-boat activities on the river.

13. <u>Development of the Basin</u>. - The principal industries are textiles, boots and shoes, and pulp and paper products. These developments are located principally in the lower basin and at water-power sites on the main stream. There is only a small amount of agriculture carried on and it is confined principally to poultry, dairy and orchard farming.

14. <u>Existing Power Development</u>. - The Androscoggin River Basin is highly developed for power, containing about 41% of the total water power capacity of the entire State of Maine. With a smaller drainage area than the Kennebec or the Penobscot, the Androscoggin River accounts for a greater total installed generating capacity than either of these rivers. Water-power developments of 100 horsepower or greater within the basin total 246,469 horsepower. Nearly all of this total is developed on the main river, about 180,000 horsepower being within the State of Maine, 60,000 horsepower in the New Hampshire portion of the river, and and balance of some 6,000 horsepower on the tributaries. Table 3, compiled from information furnished by the United States Geological Survey, contains the data pertaining to the existing installations in the basin. The locations and capacities of major water-power developments and the principal transmission lines, in relation to those in the New England States, are shown on Figure 3.

TABLE 3. WATER POWER INSTALLATIONS - ANDROSCOGGIN RIVER BASIN

(Installations of less than 100 horsepower not tabulated)

NAME OF DAM	LOCATION	OWNER	PRINCIPAL USE	OPERATING HEAD (feet)	CUMULATIVE HEAD (feet)	INSTALLED CAPACITY (horsepower)	CUMULATIVE STORAGE (acre-feet)
MAIN RIVER IN MAINE							
Brunswick	Brunswick	Central Me. Power Co.	U	14)	14	1,932	739,000
Brunswick	Brunswick	Cabot Mfg. Co.	M	14)		500	739,000
Cabot Mfg. Co.	Brunswick	Cabot Mfg. Co.	M	19)	33	4,200	739,000
Cabot Mfg. Co.	Brunswick	Cabot Mfg. Co.	M	19)		6,000	739,000
Pejepscot Mills	Brunswick	Pejepscot Paper Co.	M	22	55	8,084	739,000
Lisbon Falls Lower	Lisbon Falls	Pejepscot Paper Co.	M	13.5	68.5	1,489	739,000
Lisbon Falls Upper	Lisbon Falls	Worumbo Mfg. Co.	M	19	87.5	900	739,000
Union Water Power Co.	Lewiston	Union Water Power Co. with various lessees	M-U	50 (max.)	137.5	23,666	684,000
Androscoggin No. 3)	Auburn	Central Me. Power Co.	U	31)	169.5	10,650	671,000
Deer Rips)	Lewiston	Central Me. Power Co.	U	32)		5,500	671,000
Gulf Island	Gulf Island	Central Me. Power Co.	U	50	219.5	27,000	659,000
Livermore Falls	Livermore Falls	Int. Paper Co.	M	31	250.5	10,800	659,000
Otis	Chisholm	Int. Paper Co.	M	24	274.5	9,426	659,000
Jay	Jay	Int. Paper Co.	M	13.8	288.3	3,500	657,000
Riley	Riley	Int. Paper Co.	M	20	308.3	6,963	657,000
Rumford (3d fall)	Rumford	Oxford Paper Co.	M	30	338.3	4,669	652,000
Rumford Falls Power Co. (Middle)	Rumford	Int. Paper Co.	M	48	386.3	14,744	652,000
Rumford Falls Power Co. (Upper)	Rumford	Oxford Paper Co.	M-U	98	484.3	39,000	
Total developed on main river in Maine				484.3		179,023	

M - Manufacturing (Mostly paper & pulp mills)
U - Utility

TABLE 3 (Cont'd). WATER POWER INSTALLATIONS - ANDROSCOGGIN RIVER BASIN

(Installations of less than 100 horsepower not tabulated)

NAME OF DAM	LOCATION	OWNER	PRINCIPAL USE	OPERATING HEAD (feet)	CUMULATIVE TOTAL HEAD (feet)	INSTALLED CAPACITY (horsepower)	CUMULATIVE STORAGE (acre-feet)
MAIN RIVER IN NEW HAMPSHIRE							
Lead Mine Bridge	Shelburne	Brown Co.	M	16	500.3	3,000	644,000
Shelburne	Shelburne	Brown Co.	M	17	517.3	4,900	644,000
Twin State Gas & Elec. Co.	Gorham	Twin State Gas & Elec. Co.	U	18	535.3	2,700	644,000
Gorham	Gorham	Brown Co.	M	30	565.3	6,000	642,000
Cascade Mill	Berlin	Brown Co.	M-U	44	609.3	10,800	642,000
Cross Plant	Berlin	Brown Co.	M	21	630.3	4,750	642,000
Glen Mill No. 5	Berlin	Int. Paper Co.	M	22	652.3	4,000	642,000
Glen Mill B	Berlin	Int. Paper Co.	M	21	673.3	4,600	642,000
Glen Mill C	Berlin	Int. Paper Co.	M	37	710.3	5,100	642,000
Riverside	Berlin	Brown Co.	M	65	775.3	15,000	642,000
Total developed on main river in New Hampshire				291		60,850	

M - Manufacturing (mostly paper and pulp mills)
U - Utility

TABLE 3 (Cont'd). WATER POWER INSTALLATIONS - ANDROSCOGGIN RIVER BASIN

(Installations of less than 100 horsepower not tabulated)

NAME OF DAM	STREAM	LOCATION	OWNER	PRINCIPAL USE	OPERATING HEAD (feet)	INSTALLED CAPACITY (horsepower)
TRIBUTARIES IN MAINE						
Grants	Kennebago R.	Grants	Oquossuc Lt. & Power Co.	U	32	410
Barker Mills Lower	Little Andros. R.	Auburn	Central Me. Power Co.	U	38	800
Barker Mills Upper	Little Andros. R.	Auburn	Central Me. Power Co.	U	32	758
Minot	Little Andros. R.	Minot	Rogers Fibre Co.	M	11	224
Hackett Mills	Little Andros. R.	Hackett Mills	Rogers Fibre Co.	M	11	364
Mechanic Falls	Little Andros. R.	Mechanic Falls	Waterfalls Paper Mills	M	36	1,907
Oxford	Thompson Stream	Oxford	Robinson Mfg. Co.	M	11	315
Norway	Pennesseewassee L.	Norway	Central Me. Power Co.	U	52	450
Lisbon Centre	Sabattus R.	Lisbon Centre	Farnsworth Co.	M	18	235
Lisbon	Sabattus R.	Lisbon	Lisbon Spinning Co.	M	21	500
Sabattus	Sabattus R.	Sabattus	Park Mills Co.	M	4	133
Turner	Nezinscot R.	Turner	Central Me. Power Co.	U	14	180
Chase Corners	Martin Stream	Chase Corners	Luther M. Hodsdon	M	11	200
Hale	Swift R.	Hale	J. A. Thurston Co.	M	19	120
Total developed on tributaries in Maine						6,596
Total developed in basin						246,469

M - Manufacturing (mostly textile mills)
U - Utility

15. <u>Power Production</u>. - The total output of Maine utilities in 1935, according to the latest published statistics of the Public Utilities Commission of the state, was about 714 million kilowatt-hours of which 692 million killowatt-hours, or 97%, represent energy generated by hydro-electric plants. Nearly 32 million kilowatt-hours of additional energy was either imported from outside of the state or purchased from private power sources within the state, bringing the total distributed by Maine utilities to 746 million kilowatt-hours. Statistics of the annual generation by all utilities in Maine and separate data for the Central Maine Power Company and the Cumberland County Power and Light Company are shown in Figure 4. The Androscoggin Basin has a large volume of natural lake storage, amounting to 223 acre-feet per square mile of drainage area, as compared with 51 acre-feet on the adjacent Saco River; this large amount of storage is efficiently utilized affording a high degree of flow regulation and a corresponding enhancement of water-power production. Figure 5 shows the flow duration curves of the Androscoggin River at Rumford, Me.

16. <u>Interconnection of Operating Companies</u>. - The principal producer of power for public use in the basin is the Central Maine Power Company together with its subsidiary, the Androscoggin Electric Company. The systems of these companies are widely distributed and well interconnected for the interchange of electric power, and the Central Maine Power Company, which operates extensively in the Kennebec basin, as well, provides a tie between the generating systems of the two basins.

17. <u>Power Market</u>. - The present extent of power development in the basin amounts to 54 horsepower per square mile of drainage area, as compared with 27 horsepower for the Kennebec and 15 horsepower for the Penobscot. The well regulated flow of the

river with its great reserves of upstream storage is capable of producing much more power than is now required. Most of the plants have the capacity and water available to furnish large additional amounts of electric energy at but little increase in operating costs. The principal use of electric power in the Androscoggin basin is for manufacturing. Table 4, compiled from the Seventh Biennial Report of the Public Utilities Commission of the State of Maine, contains data concerning sales of electric energy by the Central Maine Power Company. It is believed that although this utility operates both in the Androscoggin and the Kennebec River basins, the relative figures cited in Table 4 can be regarded as representative for the Androscoggin basin.

TABLE 4. SALE OF ELECTRIC ENERGY CENTRAL MAINE POWER COMPANY - 1935

Type of Load	Energy Sold* (kwh)	% of Total	No. of Customers Served	Consumption per Customer (kwh)	Average Gross Revenue (cents/kwh)
Commercial lighting	49,559,877	13.2	77,467	640	5.25
Commercial power	236,195,238	62.8	2,131	110,837	0.85
Street lighting	4,005,960	1.1	-	-	4.64
Unclassified	41,760,186	11.1	-	-	-
Sales to other electric utilities	44,462,115	11.8	-	-	0.69
Total, distributed and sold	375,983,376	100.0			

*The total includes the energy generated by Central Maine Power Company and that purchased from other utilities.

It may be seen that nearly 63% of the total is used to meet the industrial demand; the item next in magnitude is the lighting load, accounting for over 13% of the total.

18. Estimated Future Growth. - At present the area is more than adequately supplied with power. The expansion of the load is limited by the Maine statute prohibiting the export of hydro-

electric power from the state which eliminates the metropolitan area of Boston as a possible market. Any future increase of the power demand, barring legislative action by the state is, therefore, dependent upon the following factors:

<u>a</u>. <u>Increased Industrial Activity</u>. - The industries in the Androscoggin valley are expected to participate in any general recovery from the current economic decline, subject, however, to the offsetting effect produced by the trend of the textile industry to emigrate to the South. If this trend continues, it may about balance the normal growth of the paper and pulp industry. It is probable, therefore, that for the immediate future no large increase in industrial power load will take place.

<u>b</u>. <u>Further Farm Electrification</u>. - The use of electricity on farms may provide an outlet for some of the surplus generating capacity, especially as a result of Federal aid for rural electrification. This development is already well advanced, however, since in 1934 approximately 33 per cent of the farms in the valley received electric service. In Androscoggin County this proportion was 47 per cent. A factor limiting further expansion is the continued decrease in farming activity in the State of Maine, which decline amounted to 14.5 per cent between 1920 and 1930. Extension of service to a larger number of farms, while desirable, is handicapped by the wide scattering of farm houses and by the poor economic condition of the farmer. The most promising field for further rural consumption of power appears to lie in additional use of energy for household appliances and farm machinery on farms already connected. Between 1929 and 1937 electric consumption on farms in the area served by the Central Maine Power Company increased from 370 kilowatt-hours per customer to 691 kilowatt-hours, a gain of 87 per cent.

c. Growth of Population. - The best outlook for increased power consumption is undoubtedly in the field of domestic use. With expanding industrial recovery, and normal growth of population, it is to be expected that the number of customers will increase, also that a greater consumption per customer will result.

19. Potential Power Development. - Reconstruction and modernization of older and smaller plants would result in an increased output and efficiency. This will probably be the first step towards satisfying the rising demand in this district. It is not likely, however, that new developments will become necessary in the near future. The report on this river made under the provisions of H. Doc. No. 308, 69th Cong., 1st Sess. (printed as H. Doc. No. 646, 71st Congress, 3d Session) lists 39 potential power sites with undeveloped power possibilities in excess of 100 horsepower at each site. Of these 26 were on the main river and 13 on the tributaries. After eliminating locations at existing mills and on the tributaries where the possible developments would be too small or too far removed from markets, there remained 16 sites on the main river, capable of developing 52,000 horsepower on the 90 per cent of the time basis. These potential sites ranged in size from 1400 to 6000 horsepower. Since the date of the above report, July 12, 1928, none of these sites has been developed. One reason for this is that the most favorable locations are already in use; another is the surplus generating capacity in the Androscoggin basin; a third is the ease and economy of importing power from the adjoining Kennebec basin. Redevelopment of old plants to produce more power will probably be undertaken before resorting to new construction for providing additional power. In this connection, it is reported that a number of the smaller plants, where turbines or other water wheels had been in use as prime movers of the mill machinery, the tendency

has been to abandon such a drive in favor of electric motors. In these cases it is customary to discard entirely the local power plant and to purchase energy from the public utility companies, rather than to incur the higher costs of generating it at the mill site. The scope of this report did not permit the analysis of the above mentioned potential power sites nor of the other possibilities for power development, except as they are related to a possible flood control program. The results of analyses on this basis are given in Section VI.

20. Water Supply. - The available surface and ground-water supply in the Androscoggin Basin is more than adequate for the needs of the population. Twenty-four communities in the basin, including all the principal concentrations of population, are served by water-supply systems. The sources of supply are divided about equally among lakes and ponds, wells and springs, and small streams. Treatment of the water by chlorination is provided in systems where necessary and in general the quality of water is good throughout the basin. There are numerous opportunities for additional surface and ground-water supplies if the need for them should develop and it is not expected that it will be necessary to utilize the main stream, which is subject to pollution, for water supply.

21. Sewage Disposal. - Practically all of the main stream of the Androscoggin River, beginning with Berlin, New Hampshire, and continuing through the principal cities in Maine, Rumford, Auburn, and Lewiston to tidewater at Brunswick, constitutes a major pollution problem. The principal towns along the river are industrial centers as well as concentrations of population and discharge both domestic sewage and industrial wastes into the main stream without treatment. The improvement of sanitation conditions has been the

subject of investigation by local agencies for a number of years and is considered an urgent problem at the present time.

22. Recreation. - Pollution of the main stream and the fluctuations of water levels in lakes for power-storage purposes constitute a handicap to recreational activities in some sections of the basin. There are numerous small lakes and ponds and small tributary streams in the lesser developed portions of the basin which offer recreational opportunities.

III. METEOROLOGY, HYDROLOGY AND FLOOD HYDRAULICS

23. General Climate. - The Androscoggin River watershed has a variable climate, characterized by frequent, but short, periods of heavy precipitation. The region lies in the path of those planetary winds known as the "prevailing westerlies"; and the succession of high and low barometric pressures which accompanies these prevailing westerly winds causes unsettled weather. Occasional tropical storms have moved up from the south and have traversed the region. High summer temperatures support an abundant and varied plant life, while for three to four months in winter the temperatures are well below freezing. A heavy annual snowfall results from the sustained low temperatures of winter.

24. Records of Temperature and Precipitation. - The United States Weather Bureau has maintained nine observation stations for temperature and precipitation in the Androscoggin watershed. Records from these stations have been supplemented by records from three stations located in adjacent areas. All stations used in this study of the Androscoggin River are listed in Table 5 following.

TABLE 5. OBSERVATION STATIONS FOR TEMPERATURE AND PRECIPITATION

Station	Elevation (Feet above M.S.L.)	Period of Record	Length of Record (Years)
Oquossuc Dam, Me.	1534	1900-1930	31
Upper Dam, Me.	1484	1886-1937	52
Middle Dam, Me.	1430	1904-1937	34
Aziscohos Dam, Me.	1528	1911-1933	23
Errol, N. H.	1260	1885-1937	53
Milan, N.H.	1190	1887-1898 1926-1937	24
Berlin, N.H.	1110	1887-1903 1918-1937	37
Rumford, Me.	505	1893-1937	45
Lewiston, Me.	182	1874-1937	64
Farmington, Me.*	425	1891-1937	47
Gardiner, Me.*	139	1836-1937	102
North Bridgton, Me.*	450	1893-1937	45

* Located outside the Androscoggin Basin.

25. Temperature Statistics. - The mean annual temperature as determined from the records of four stations (Berlin, Rumford, Lewiston and Farmington) is 42.7 degrees Fahrenheit. Mean monthly and annual temperatures at these stations are given in Table 6, following.

TABLE 6. MEAN MONTHLY AND ANNUAL TEMPERATURE - DEGREES FAHRENHEIT*

Month	Berlin,N.H.	Rumford,Me.	Lewiston,Me.	Farmington,Me.	Average for the basin
Elev.	1110	505	182	425	
Jan.	13.5	16.7	18.2	15.6	16.0
Feb.	15.6	17.7	18.9	17.4	17.4
Mar.	27.5	29.1	29.8	28.9	28.8
Apr.	39.7	41.1	41.9	41.9	41.2
May	52.0	53.2	53.9	54.2	53.3
June	61.0	60.4	63.5	63.1	62.0
July	66.2	68.4	69.4	68.1	68.0
Aug.	63.2	65.2	66.8	65.6	65.2
Sept.	56.4	58.0	59.5	58.0	58.0
Oct.	45.9	47.3	48.8	47.2	47.3
Nov.	32.5	33.9	35.8	34.0	34.1
Dec.	18.8	21.8	23.3	21.3	21.3
Annual	41.0	42.7	44.2	42.9	42.7

*For the period of record through 1935.

26. Precipitation Statistics. - The mean annual precipitation as determined from the records of nine stations (Upper Dam, Middle Dam, Errol, Berlin, Rumford, Lewiston, North Bridgton, Farmington and Gardiner) is 39.4 inches. Mean monthly and annual precipitations at these stations are given in the following table. (Also see Figure 6).

TABLE 7. MEAN MONTHLY AND ANNUAL PRECIPITATION IN INCHES (THROUGH 1935)

Month	Upper Dam	Middle Dam	Errol, N.H.	Berlin, N.H.	Rumford, Me.	Lewiston, Me.	N. Bridgton, Me.	Farmington, Me.	Gardiner, Me.	Average for the basin
Elev.	1484	1430	1260	1110	505	182	450	425	139	
Jan.	2.44	2.05	2.78	2.95	2.88	3.84	3.46	3.29	3.59	3.03
Feb.	2.06	1.84	2.61	2.82	2.91	3.73	3.34	2.95	3.44	2.86
Mar.	2.55	2.18	2.82	3.33	3.32	4.28	3.91	3.90	3.91	3.35
Apr.	2.18	2.42	2.60	2.65	3.22	3.42	3.45	3.29	3.33	2.95
May	2.93	3.33	2.97	2.91	3.28	3.47	3.55	3.68	3.64	3.31
June	3.26	3.56	3.79	3.63	3.53	3.48	3.58	3.68	3.23	3.53
July	3.25	3.61	3.78	3.50	3.67	3.60	4.19	3.45	3.37	3.60
Aug.	3.28	3.96	3.95	3.61	3.58	3.21	3.64	3.87	3.51	3.64
Sept.	3.15	3.52	3.43	3.10	3.50	3.52	3.70	3.59	3.33	3.43
Oct.	2.51	3.01	3.10	3.04	3.19	3.59	3.21	3.44	4.08	3.24
Nov.	2.78	2.85	3.11	3.44	3.36	3.83	3.61	3.59	3.93	3.39
Dec.	2.38	2.11	2.82	2.98	2.90	3.91	3.44	3.46	3.64	3.07
Annual	32.77	34.44	37.76	37.96	39.34	43.88	43.08	42.19	43.00	39.40

27. Snowfall. The annual snowfall on the Androscoggin watershed varies from 77 inches on the coast to 130 inches on the northern headwaters. (See Figure 7). For a number of years the power companies operating on the Androscoggin River have conducted snow surveys throughout the winter in the Rangeley Lakes region. By means of these surveys the companies obtain data regarding the "snow cover", that is, the depth of snow on the ground and its water equivalent. These data are utilized in operating the storage reservoirs which are filled each spring by run-off from the accumulated snow and incidental rainfall. For the past two years the surveys have been complete enough to show the gradual accumulation of snow blanket throughout the winter (see Figures 8 and 9). The depletion of the snow cover during March, 1936 is shown on Figure 10. An additional study was made of the snow run-off from that portion of the watershed between Errol, New Hampshire, and Rumford, Maine. Estimates were made of the minimum amount of run-off attributable to snow during the months of March, April, and May in the period from 1925 through 1935 by deducting from the total observed flow, the run-off from rainfall as computed by means of the unit-graph method. Assuming 100% run-off from rainfall, the excess of observed run-off over that computed for rainfall alone may be attributed to melting snow. It was found that the average total run-off thus attributable to snow amounted to about 5.25 inches over an average period of about 18 days. This represents an average rate of nearly 0.3 of an inch per day during the period when snow is melting and running off.

28. Stream Flow Records. - Data concerning 11 stream gaging stations in the basin operated by the United States Geological Survey are shown in Table 8 following. Information concerning the accuracy of the records is given in Water Supply Paper No. 781.

TABLE 8. STREAM GAGING STATIONS

Location of Gaging Station	Drainage Area (sq.mi.)	Period of Record	Discharge in Cubic Feet Per Second: Mean	Maximum **	Minimum
Androscoggin River					
Errol Dam, N.H.	1095	1905-1923	Completely Regulated		
Berlin, N.H.	1380	1913-1922	2180	14,300	*
Gorham, N.H.	1390	1929-1937	2360	19,900	960*
Shelburne, N.H.	1500	1903-1907	---	15,600	*
Rumford, Me.	2090	1892-1937	3480	74,000	*
Dixfield, Me.	2230	1902-1908	4940	---	*
Gulf Island, Me.	2860	1936	---	118,000	1550*
Auburn, Me.	3257	1928-1937	5420	135,000	465*
Magalloway River					
Aziscohos Dam, N.H.	233	1912-1935	Completely Regulated		
Swift River					
Roxbury, Me.	95	1929-1937	178	13,000	5
Little Androscoggin River					
South Paris, Me.	76	1913-1924 1931-1937	139	6,980	1

* Flow regulated by controlled storage
** Instantaneous peak discharges

29. Run-off Statistics. - The mean monthly flow of the Androscoggin River at Rumford, Maine, with the equivalent run-off, is given in the following table.

TABLE 9. MEAN MONTHLY FLOW AT RUMFORD, MAINE (Through 1936)
(Drainage Area 2090 square miles)

Month	Discharge: Cubic Feet Per Second	Discharge: Cubic Feet Per Second Per Square Mile	Equivalent Run-off in Inches
January	2460	1.18	1.36
February	2320	1.11	1.16
March	3760	1.80	2.07
April	7260	3.47	3.88
May	6830	3.27	3.77
June	3920	1.88	2.09
July	2510	1.20	1.38
August	2240	1.07	1.24
September	2310	1.11	1.23
October	2550	1.22	1.41
November	3090	1.48	1.65
December	2500	1.20	1.38
Annual	Mean 3480	Mean 1.67	Total 22.62

30. <u>General Flood Situation</u>. - The Androscoggin Basin is exposed to storms which are capable of producing heavy rainfall and which, especially in combination with a rapid melting of snow cover, may cause extreme floods. In addition, the flood situation is often complicated by ice conditions, that is, ice jams and damage to structures by solid, floating ice. In general, however, the resulting flood damages on the upper reaches of the river are not severe because the area is sparsely settled and developed and because the cities and towns are located on rising ground. On the central and lower portions of the river (below Rumford) the valley is more developed agriculturally and industrially. The cities are built on lower ground adjacent to the river and serious damage results in this section from the more severe floods of comparatively infrequent occurrence.

31. <u>Effect of Snow</u>. - Melting snow has an important effect upon stream flow in this basin. It is nearly always a contributary factor to major floods and often it is the main cause. The results of snow surveys and studies are described in paragraph 27. These studies, as well as information contained in the United States Geological Survey Water Supply Paper No. 798, "The Floods of March 1936, Part I, New England Rivers" indicate that there were at least three inches, and possibly more, of run-off due to melting snow during the March, 1936 flood.

32. <u>Effect of Ice</u>. - Ice is also a factor in the floods which occur early in the spring. The river flows in a southerly direction; consequently, the ice in the lower reaches normally softens and goes out sooner than that in the upper reaches and headwaters. When the spring break-up occurs early, however, ice jams made up of thick, solid "blue ice", are likely to form at

obstructions in the river. Ice jams which formed during the floods of March, 1936, carried out a railroad bridge at Brunswick and caused much physical damage to other structures before eventually passing downstream. At Rumford an ice jam was successfully passed by regulation of the river at Errol, temporarily reducing the stage of the river until the jam had passed.

33. Types of Storms. - The storms which occur in the Androscoggin Basin are of three general types: (1) extratropical cyclones, (2) tropical hurricanes and (3) rain storms caused by the rapid displacement upward of a warm air mass by a colder, denser air mass, usually accompanied by an extratropical cyclone or tropical hurricane. Of these, the extratropical cyclones are the most numerous. From two to five such storms per month pass over New England over varying paths and from widely scattered origins. They occur throughout the year and form the main factor in providing uniform year-round precipitation. The most severe rains are caused by the second and third types which are less frequent and are dependent on other combinations of meteorological factors for their occurrence in New England.

34. Extratropical Cyclones. - The shifting of air masses from one locality to another causes the planetary circulations of the atmosphere to proceed, with a general eastward trend, in great atmospheric whirls producing disturbances marked by an area of low barometric pressure at their center and called extratropical cyclones. The storms are usually accompanied by variable amounts of precipitation depending on their origin and paths. When the "lows" follow transcontinental paths, their moisture content is generally moderate but as they pass over the Androscoggin watershed from land to sea, the vertical winds in the front sector sometimes bring moisture-laden air inland from the Atlantic Ocean. This movement is often assisted by

the presence of an area of high barometric pressure offshore or in the northeast over Newfoundland. Clockwise winds of the "high" reinforce the counter-clockwise winds of the "low" producing local onshore winds which are undoubtedly a factor in increasing normal precipitation. Some of the storms of extratropical origin follow a coastal path in approaching New England. These usually have a high moisture content and result in higher than average precipitation. The first of the two storms causing the March, 1936 flood is an example of a coastal extratropical cyclone. This storm, however, was accompanied by a movement of warm and cold air masses and the resulting precipitation was higher than usually occurs with a coastal extratropical cyclone alone.

35. Tropical Hurricanes. - A frequent path of tropical hurricanes is westward from the West Indies towards the Gulf of Mexico, from whence a storm occasionally veers abruptly to the northeast and moves up the Atlantic coast, causing heavy rainfall in the southern Alleghenies. In travelling over the land the storm usually becomes greatly reduced in violence and precipitates most of its moisture before reaching New England. Occasionally, however, such a storm attains sufficient force to carry its moisture into New England and causes very heavy rainfall. On September 16, 1932, a tropical hurricane caused rainfall of 8.3 inches at Kingston, Rhode Island and the eight-inch isohyetal included areas in Maine and New Hampshire. The occurrence of these hurricanes is limited to late summer and early fall.

36. Movement of Air Masses. - In addition to the two general types of storms described above, there is a third type of disturbance important from a flood standpoint, namely, the severe rainfall caused by the rapid displacement upward of a warm air mass by a colder, denser air mass. This type is not strictly classifiable

as a "storm" but represents rather a combination of climatological phenomena producing results that cannot be classified as characteristic of either extratropical cyclones or tropical hurricanes, although either one of those types of storm is usually a part of the combination of conditions attendant upon air mass movements. The principal factors which distinguish these combinations as a storm type are: (1) steady rainfall of greater than average intensity and duration over a comparatively large area as contrasted with the more moderate rainfall of long duration over a smaller area for extratropical cyclones and the more severe rainfall but of shorter duration for tropical hurricanes; (2) the possibility of occurrence of the necessary combination of phenomena at any time of year as against the limited season for tropical hurricanes; and (3) the effect on a snow-covered watershed of unseasonably warm weather which usually accompanies the influx of the warm, moist air mass to the region. This factor is very important in the Androscoggin Basin where the inclusion or exclusion of snow run-off during a severe rain storm often represents the difference between a non-damaging and damaging flood.

37. Record of Past Floods. - The five highest floods of record on the Androscoggin River at Rumford, Maine (drainage area 2,090 square miles, of which 1,095 square miles are completely controlled) were as follows:

TABLE 10. FLOOD FLOWS - ANDROSCOGGIN RIVER AT RUMFORD, ME.

Order of Magnitude	Date	Average 24-hour Discharge (c.f.s.)	Peak Discharge (c.f.s.)	Average 24-hour Run-off in c.f.s. per square mile
5	May 18, 1893	38,100	-	18.2
2	April 15, 1895	55,200	-	26.4
4	March 2, 1896	39,000	-	18.6
3	November 5,1927	39,100	46,700	18.7
1	March 19, 1936	68,300	74,000	32.6

The March 1936 flood was the greatest in the lower reaches of the Androscoggin River since the beginning of systematic records in 1892. United States Geological Survey has published, in Water Supply Paper No. 798, a collection of notes regarding early floods in this basin from sources believed to be authentic. These notes refer to floods as far back as February, 1723 and indicate that damages, especially to bridges and mills, were suffered in 1785, 1814, 1820, 1826, 1827, 1846, 1869, 1895 and 1896. The notes also indicate that the March 1936 flood exceeded all previous flows except, possibly, those of 1785.

38. <u>The Flood of March, 1936</u>. - The maximum discharge of 68,300 c.f.s. exceeded the highest previously recorded (in 1895) by nearly 25 per cent and the flood losses were many times greater than any previously suffered. The flood was caused by a succession of two storms within a period of 11 days. Rainfall for the period March 10 to 20 was heavy throughout the entire New England area, varying from a few inches along the coast to a maximum of about 20 inches in the White Mountains, which are the common headwaters of the Connecticut, Merrimack, Kennebec and Saco Basins, as well as the Androscoggin Basin. Four lives were lost in the Androscoggin Basin during the flood and over 1,500 families, involving about 6,000 people, were temporarily homeless. About 2,000 buildings were affected by the flood. Eighteen bridges were wholly or partially destroyed and ten additional bridges suffered some damage. Although the actual area flooded was not large, several towns were practically cut off from the outside world for from one to four days as railroad, highway, telephone and telegraph facilities were disrupted. Several towns were temporarily without light, power and water. The depth of water in the area flooded varied greatly. In the towns and cities a few principal streets were covered to depths

of from one to five feet generally, although depths as great as 15 feet were reported in Brunswick, Maine. The total damages suffered in the basin were over four million dollars. More detailed figures for damages are given later in this report. In the paragraphs immediately following, the meteorological and hydrological conditions affecting the flood are summarized. A complete description of the flood is given in Water Supply Paper 798 of the United States Geological Survey.

39. General Watershed Conditions - March, 1936. - The winter's snowfall of 63.5 inches for the three northern states of New England, for the three months of December, January and February, 1935-1936, was 8.2 percent above the 15 year average for that three-month period. The temperature, moreover, had been below normal for the three months preceding March, 1936. The average daily deficiency for the three states was about 9.1 degrees, indicating only slight thawing and melting of snow during the winter and suggesting that practically all of the winter's snow was on the ground at the beginning of the storms. Furthermore, the snow cover's capacity to absorb rainfall was probably large because the prevailing cold weather had been conducive to lesser consolidation than if there had been alternate freezing and thawing. Studies of the snow run-off indicate that it is very likely that much of the first storm's rainfall was absorbed by the snow cover and discharged with the run-off of the second storm.

40. The First Storm - March 11-13, 1936. - The storm was an extratropical cyclone which originated somewhat south of the usual origin of such storms and followed a path diverging southward and easterly of customary routes. On the northern leg of its journey, it probably marked the edge of a tropical air mass. While the southern

storm was moving toward New England along the Atlantic Coast, another storm generated in the region of the southern Rocky Mountains and moved across the continent to Ontario, Canada. The two storms began to coalesce on March 12 with a decrease in barometric pressure. The union was completed on the 13th, with a drop in pressure to 28.90. This drop in pressure undoubtedly contributed much to the movement of warm moisture-laden air over New England. The Blue Hill Meteorological Observatory reported (Monthly Weather Review, March, 1936) that a tropical air mass from the Atlantic was being underrun by a continental air mass. By March 13 the tropical air had been replaced by cold continental air. The presence of the warm tropical air accounts for the abnormally high temperatures and its underrun by the cold air was the cause of the heavy precipitation.

41. <u>The Second Storm - March 17-19, 1936.</u> - This storm was first observed east of the Rocky Mountains in the region from Colorado to Montana. After remaining there two days, it moved southward to Texas and thence northeastward to New England. After March 15, this "low" was closely followed from the west by a "high" which extended from the Gulf of Mexico to north-central Canada. Another stationary "high" remained over the Canadian Maritime Provinces and Newfoundland during the time that the "low" moved along its course. The existence and course of the "low" do not tell the entire story of the causes of the heavy rainfall in the New England area. Rain began on March 16 when the "low" was moving toward the Carolinas and continued while the "low" moved only from there to Virginia. The maximum rainfall in New Hampshire occurred on March 18, while the storm moved from Virginia to New England. The movement of the area of depressed barometric pressure does not account wholly for the early rain in New England. However, this "low" and the general trend of the isobars suggest very strongly that a movement of an

air mass from the Gulf and West Indies regions to New England occurred while the "low" was traveling northward. This movement would amply account for all rainfall and other circumstances of precipitation.

42. Precipitation of the Storms of March, 1936. - The heaviest precipitation occurred in the White Mountains, New Hampshire, in the headwaters. The amount of daily precipitation in and near the Androscoggin Basin is given in the following tabulation for the period March 10-20:

TABLE 11. PRECIPITATION - MARCH 10-20, 1936

Station	Precipitation on each day - in inches											Total for 11 days
	10	11	12	13	14	15	16	17	18	19	20	
Berlin, N.H.	.21	.02	1.68	1.01	.02	T	.09	.89	.52	2.20	.42	7.06
Errol, N.H.	.08	-	1.24	.37	.08	-	.66	.70	.81	-	-	3.94
Farmington, Me.	.15	T	3.53	.68	-	-	.71	.24	.36	2.27	.06	8.00
Lewiston, Me.	.17	.13	3.07	.37	-	-	.02	.10	.65	1.60	-	6.11
Middle Dam, Me.	-	-	1.96	.52	.08	-	.56	.62	2.30	1.60	-	7.64
Milan, N.H.	-	.04	1.03	.39	-	-	.58	.82	.74	.63	-	4.23
N.Bridgton, Me.	.20	.14	3.78	.43	-	-	.35	.14	.72	2.85	.08	8.69
Portland, Me.	.12	.25	1.23	.24	-	T	.03	.03	.22	.73	-	2.85
Rumford, Me.	-	.38	5.07	.39	T	-	.81	.26	1.60	1.29	.45	10.25
Upper Dam, Me.	-	-	2.10	-	-	-	1.27	-	1.18	1.19	-	5.74

43. Procedure for Selection of Design Floods. - The general procedure for the determination of the meteorological and hydrological conditions upon which to base design floods was as follows: First, the selection of basic meteorological conditions; Second, the determination of appropriate watershed conditions, including the run-off-rainfall ratio and amount of snow run-off to be expected, and third, construction of plan or design floods.

44. General Flood Conditions for Which Protection is Required. - Consideration of the records of past floods in the Androscoggin and

other New England basins led to the conclusion that the plan flood for which flood protection is required in this basin should be similar to the March, 1936 flood both in magnitude and in manner of occurrence. The March, 1936 flood was the greatest on record and was general throughout the basin. It is realized that greater floods may occur and the possibility of such occurrence was provided for in the design of all structures and in determining the height of local flood protection works such as levees or river walls. The March, 1936 flood, therefore, was used as the plan flood for reservoir control and a reservoir system was sought which would give the greatest degree of control of this flood possible within economic limits. Local flood protection possibilities were designed to provide for the March, 1936 flood plus adequate freeboard for possible larger floods.

45. Design Floods for Reservoir and Outlet Capacities. - The design floods for reservoir and outlet capacity were based on meteorological conditions of reasonable frequency rather than the extreme conditions of rare frequency in order that maximum efficiency of reservoir control would be obtained for floods of most frequent occurrence. Accordingly, outlet design floods were constructed for each reservoir studied based on a three-day storm of 100-year frequency plus a prior, ground-saturating storm of 4.5 inches in three days. The construction of the design floods and their use in the determination of reservoir and outlet capacity are discussed in Section V.

46. Spillway Design Floods. - The spillway design floods were based on an estimate of the most unfavorable meteorological and ground conditions probable regardless of the frequency of such conditions. A study for the purpose of determining probable future maximum amounts of precipitation for use principally as a criterion for

the safe design of spillways was conducted by the U. S. Weather Bureau in cooperation with the Corps of Engineers, U. S. Army, for the nearby Merrimack River Basin. The results of this study were used as a guide in the selection of the basic amounts of precipitation and allowance for melting snow in the Androscoggin Basin and a factor of safety of 50% on both rain and snow was added. The actual construction of the spillway design floods on this basis is described in Section V.

47. Rainfall-Run-off Relations. - The amount and manner of the run-off into stream flow which will result from rainfall is dependent upon topographic, geological and other physical features of the watershed, including degree of saturation, frost, snow and ice conditions, infiltration, transpiration and evaporation. Accurate evaluation of the separate factors affecting run-off is impracticable, if not impossible. However, the sum of the effects of the factors is eliminated from the total rainfall and the residue in terms of run-off determined by comparing the observed run-off which may be definitely identified with specific amounts of observed rainfall. This procedure, known as the unit-graph method, is described in U.S.G.S. Water Supply Paper No. 772, "Studies of Relations of Rainfall and Run-off in the United States" and in other publications listed in that paper. Briefly, the procedure followed in utilizing the unit-graph method was to examine the precipitation records for storms which had durations of 24 hours or less and which were followed by several days of little or no precipitation. From examination of the run-off records for the periods immediately following the rains, those one-day storms were singled out which produced appreciable peaks in stream discharge. A unit hydrograph, which is the hydrograph of surface run-off produced by a rain of unit duration, was then derived for each storm by subtracting from the stream discharge the amounts estimated to be run-off from previous or succeeding storms or from ground water. A distribu-

tion graph for each storm was derived by plotting as ordinates the percentages which succeeding daily discharges are of the total discharge against days as abscissas. Mean distribution curves for watershed areas above gaging stations were then constructed from the superimposed graphs of the storms in each area. Table 12 gives the daily percentages of run-off from one-day storms taken from the mean distribution graphs.

TABLE 12. DAILY DISTRIBUTION FACTORS

Order of days	% of Total Unit Storm Run-off Occurring on Successive Days at:			
	Androscoggin River at Rumford	Androscoggin River at Auburn	Little Androscoggin River at S.Paris	Swift River at Roxbury
1	15.9	9.1	21.7	15.3
2	42.6	29.1	45.2	45.7
3	20.5	27.3	15.7	20.4
4	9.6	15.1	7.9	9.0
5	5.6	8.3	5.0	4.9
6	3.2	5.1	3.0	2.8
7	1.9	3.2	1.4	1.5
8	0.7	1.9	0.1	0.4
9		0.8		
10		0.1		

48. Frequency Studies. - Although flood control works must be designed to be safe under the most extreme conditions possible regardless of their probable. frequency, it is, nevertheless, necessary to determine, as accurately as possible with the information available, the probable frequency of occurrence of the various magnitudes of precipitation and stream flow for use in other phases of the flood control study as follows:

(a) Economic analysis of flood protective works.
(b) Design floods for reservoir capacity and operation.
(c) Analysis of the relative requirements for flood control in various seasons of the year.

The accuracy of any frequency computation is dependent, primarily, on the record of events. Since precipitation and stream-flow records are, in most cases, only a short and not necessarily a truly representative sample of the full record, the frequencies computed from short records should be used with caution. However, where records of reasonable length are available and accurate methods of frequency computation are used, the results are useful, particularly for determining <u>relative</u> rather than quantitative conditions. In the studies for this report, the design floods for reservoir and outlet capacities were constructed by the unit-graph method from rainfall based on the computed precipitation frequencies. For the economic analysis of flood protective works, computed discharge frequencies were obtained for the control points at each of the damage reaches. The results of the frequency studies are illustrated in the following tabulations.

EXPECTED FREQUENCY OF RAINFALL

Period	Rumford, Me.	Berlin-Bethlehem, N.H.
Once in 1 year	2.0 inches or more	1.7 inches or more
Once in 10 years	3.8 inches or more	3.2 inches or more
Once in 25 years	4.8 inches or more	4.1 inches or more
Once in 50 years	5.5 inches or more	4.8 inches or more
Once in 75 years	5.9 inches or more	5.2 inches or more
Once in 100 years	6.3 inches or more	5.6 inches or more

EXPECTED DISCHARGE AT RUMFORD, MAINE

Period	24-Hour Discharge in c.f.s.
Once in 1 year	20,000
Once in 10 years	38,000
Once in 50 years	54,000
Once in 75 years	59,000
Once in 100 years	62,000

Very rare floods with peak discharges approaching 90,000 cubic feet per second may also occur. The foregoing figures are for 24-hour discharges. Frequency curves based on instantaneous peak flows are shown on Figures 31, 33, 35 and 37.

IV. FLOOD DAMAGES

49. Information Available. - There are no records available of the damages caused by floods in the Androscoggin Basin prior to the flood of March, 1936. According to information published by the U. S. Geological Survey in Water Supply Paper 798, damages, especially to mills and bridges, were suffered in 1785, 1814, 1820, 1826, 1827, 1846, 1869, 1895 and 1896. No estimates of the amount of damage are obtainable for these early floods. Complete statistics are available, however, of the damages caused by the flood of March, 1936. High-water stages exceeded all those previously recorded in practically every section of the basin and flood damages were suffered throughout the valley generally. The data on losses caused by this flood, therefore, are most useful for the purpose of economic analysis of flood protection works.

50. Survey of Flood Damages, March, 1936. - An estimate of the flood losses, both direct and indirect, caused by the flood of March, 1936, in the Androscoggin Basin was obtained immediately following the flood by means of a thorough canvass of individual sufferers throughout the basin. The losses were estimated at the site of the damage and, where possible, in direct conference with the person or persons best qualified to make the estimate. In addition to the estimate of the total loss at each specific location, the increment of loss attributable to selected intervals of stage was also estimated at the site. These figures for damages by increments of stage were then summarized by separate reaches of the river and the incremental damages referred directly to the stage at a definite control point in each reach. The elevations for referring the damages to the control points were obtained by means of a high-water-profile survey which was conducted simultaneously with the damage survey.

51. Direct Damages. - The estimate of the direct losses included all items of physical damage to property such as buildings,

equipment, supplies, manufactured goods and records and all direct expense necessitated by the flood emergency. In the compilation the damage figures were grouped into the following classes:

<u>Industrial</u>. - manufacturing establishments.

<u>Commercial</u>. - trading establishments, wholesale and retail stores and warehouses, banks and professional offices.

<u>Farm and Rural</u>. - agricultural land and forests.

<u>Utilities</u>. - electric power, gas, sewage disposal plants, waterworks, telephone and telegraph.

<u>Railways</u>. - steam lines, interurban electric lines and bridges.

<u>Highways</u>. - highways and streets.

<u>Highway Bridges</u>.

<u>Residential</u>. - grounds, buildings, equipment, personal property, furniture and furnishings.

<u>Federal, State and Municipal</u>. - damage to property of these agencies and cost of emergency relief furnished by them.

52. <u>Indirect Damages</u>. - Wherever possible an estimate of indirect losses was obtained from all individuals and agencies reporting direct damage. The indirect losses consisted principally of loss of business caused by the cessation of productive industry or commerce. Also reported were such items as increased cost of utility service during the time of flood and the additional haulage costs necessitated by re-routing of trains around inundated areas. A thorough analysis was made of the reported figures for direct and indirect losses in order to determine possible omissions of indirect losses. Whenever flood conditions exist over a large area there are many indirect losses attributable to the flood on which information is virtually uncollectible by any ordinary census. The flood damage survey revealed several possible items of this type of loss for which no complete statistics could be gathered. They included business losses to firms outside the actual flooded area, increased transportation costs on highways

because of detours, the depreciation of value of totally or partially undeveloped property because of its liability to flooding and many intangible items of loss throughout the flooded area and adjacent territory resulting from the disruption of routine affairs. A few examples of the foregoing types of loss were actually reported. A study was made for the purpose of estimating the amount which should be added to the reported damages for these intangible or uncollectible losses. It is believed that an allowance for the unreported indirect losses may be conservatively estimated as about equal to the indirect losses actually reported. Accordingly, an amount equal to the actual indirect losses reported was added to the reported figures to form a basis for computation of the annual value of the complete elimination of flood damage. Of the total damages of $4,392,000 in the Androscoggin Basin, $4,232,000, or 96% were in the State of Maine and the remainder, only 4%, in New Hampshire. The direct and indirect damages suffered in the Androscoggin River Basin in the March, 1936 flood are shown in Table 13 below.

TABLE 13. FLOOD DAMAGES - ANDROSCOGGIN RIVER BASIN - MARCH, 1936

Class	Indirect	Direct	Total
Industrial	$ 634,500	$ 867,000	$ 1,501,500
Commercial	87,200	302,200	389,400
Farm and Rural	900	232,600	233,500
Residential	2,600	319,600	322,200
Railroads*	86,800	290,900	377,700
Highways*		550,300	550,300
Utilities	6,000	149,200	155,200
Public Funds (Municipal)		44,200	44,200
Total Reported	$ 818,000	$ 2,756,000	$ 3,574,000
Estimated Unreported	$ 818,000	-	$ 818,000
Grand Total	$ 1,636,000	$ 2,756,000	$ 4,392,000

*Includes bridges

53. Computation of Annual Flood Loss. - As described in paragraph 50, the amounts of damage at selected increments of stage up to the maximum were determined during the field survey. On the basis of the existing value of the developments in the basin subject to flood damage, the amount of damage which would be caused by a flood of any magnitude up to that of March, 1936, can be computed. This was done by summarizing for each reach the total damage at each selected stage referred to a definite control point (also designated as the damage center) for the reach and plotting a curve of the stage-damage relation. By means of a rating curve for the control point, a second curve was plotted giving the discharge-damage relation. The discharge-damage curves for the four reaches used on the Androscoggin River are shown on Figures 32, 34, 36 and 38. The expected frequency at each stage of discharge was computed from existing records at all control points where such records were available. The frequency curve for the reaches are shown on Figures 31, 33, 35 and 37. Taking the amount of damage for selected increments of discharge equal to about one foot in stage at the control point, a curve was plotted giving the damage-frequency relation for a 250-year period. These curves for the various reaches are also shown on Figures 32, 34, 36 and 38.

54. Annual Value of Complete Elimination of Flood Damage. - The procedure outlined in the foregoing paragraph was followed in computing the annual flood damage in each reach of the river. The solution was derived both mathematically and graphically and the results were found to be well within the limits of accuracy for data used. The stage-damage curve, the frequency curve and the damage-frequency relation for each principal reach are shown on Figures 31 to 38. The summary of the total annual flood losses for each principal reach is given in Table 14. These totals represent the annual value of the complete elimination of flood damages in the reaches considered.

TABLE 14. COMPUTED ANNUAL FLOOD LOSSES

Damage Center	Computed annual losses (direct only)	Ratio of indirect to direct losses	Computed annual indirect losses	Total average annual losses	% of grand total
Lisbon Falls	$ 74,700	0.480	$ 35,900	$110,600	24.4
Auburn	30,400	0.702	21,300	51,700	11.4
Livermore Falls	79,600	0.522	41,600	121,200	26.7
Rumford	87,300	0.946	82,600	169,900	37.5
Total	$272,000	0.667	$181,400	$453,400	100.0

55. Summary of Flood Damage Factors. - In general, the area subject to flooding in this basin is not large, but a large amount of industrial property is subject to damage during extreme floods. Many of the industries of this region, consisting primarily of textile, boot and shoe, and pulp and paper mills, are located immediately adjacent to the normal river channel. Similarly, the commercial sections of several communities are located near the waterfront. These developments, together with power plants and bridges, are subject to appreciable losses within a comparatively small extent of flooded area. They are seriously affected, however, only by the more extreme floods. The amount of agricultural land flooded may be extensive for the extreme stages but the damage is moderate because the floods usually occur in the spring before crops have been planted. With the exception of bridges which, in many cases, have been rebuilt at higher elevations, most of the developments are subject to recurring damage. In general, the benefits of adequate flood control measures would be confined to the value of the elimination of flood damage to existing developments and would have little effect on increasing the value and productivity of the area subject to flooding.

V. DEVELOPMENT OF A FLOOD CONTROL PLAN

56. Possible Methods of Control. - The more important and most generally applicable methods of flood control or protection against flooding are, (1) control by reservoirs, (2) protection by levees or river walls, (3) lowering of flood stages by channel improvement or rectification and (4) diversion of flood flows into auxiliary channels. The possibilities of using each method as the principal means of providing flood protection in the Androscoggin Basin are discussed in following paragraphs. Consideration has also been given to combinations of these methods. The results of the studies are discussed in the following order:

(a) Reservoir control.

(b) Levees and river walls.

(c) Channel improvements.

(d) Diversion of flood flows.

57. Reservoir Control. - Flood protection by means of an adequate and properly located system of reservoirs has the advantage of controlling floods at their source and thus protecting, in varying degrees, all downstream points. The degree of protection afforded any point diminishes as its distance from the reservoir increases. Therefore, reservoirs located immediately upstream of the principal damage centers are desirable. The degree of control is also dependent on the amount of run-off which is stored or delayed and thus kept from adding to the peak of the flood. The studies of both the Miami and the Muskingum Conservancy Districts revealed that a given amount of storage is more effective when contained in a few large reservoirs than in a greater number of small reservoirs. Normally, the most desirable reservoir system is one of a few large reservoirs

controlling large drainage areas and located as close to the principal damage centers as possible. The reservoirs in a system should be well distributed geographically so as to provide protection from storms centering over any tributary.

58. Procedure for the Study of Reservoir Control. - Investigation of the possibilities of reservoir control in the Androscoggin Basin was undertaken in two stages: (1) preliminary investigation of 25 prospective reservoir sites, and (2) detailed study of the four reservoirs offering the most favorable possibilities. The reservoirs were grouped by tributaries for the process of elimination. Individual reservoir capacities were sought which would be equivalent to about five to seven inches of run-off from the drainage area above, this range of capacity having been determined as sufficient, with a proper distribution of reservoirs, to control the March, 1936 flood without exceeding safe channel capacity.

59. First Stage of Reservoir Selection. - Preliminary estimates of cost and reservoir capacity were made of 25 sites in the Androscoggin Basin capable of controlling the March, 1936 flood and having drainage areas in excess of 10 square miles. The estimates were based on data obtained from the U. S. Geological Survey topographic quadrangle maps and by field reconnaissance. The location of the sites investigated is shown on Figure 11. The main stream above Errol is controlled by the conservation storage in Umbagog, Aziscohos, Kennebago, Rangeley, Mooselookmeguntic and Richardson Lakes which are regularly drawn down during the winter months in anticipation of the spring run-off. With such storage, controlling a drainage basin of approximately 1100 square miles, operative, further control in this area was deemed unnecessary. Similar conditions prevail on the Dead River, where Androscoggin Lake and a series of ponds develop a considerable amount of storage. It was found that

reservoir control on the Swift River would entail high damage and construction costs, factors which eliminated the sites on this tributary. The reservoirs finally selected as most desirable were Rumford on the main stream, Dixfield on the Webb River, Buckfield on the Nezinscot River, and Oxford on the Little Androscoggin River. These four reservoirs, therefore, were selected for more detailed study and analysis of costs and flood control benefits.

60. Second Stage of Reservoir Selection. - The four reservoirs selected for detailed study were investigated as follows:

(a) Topographic survey of the reservoir area.
(b) Property appraisal survey.
(c) Topographic survey of the dam site.
(d) Geological reconnaissance of the dam site.
(e) Preliminary design of structures, including rigid analyses of spillway and outlet conditions.
(f) Detailed estimate of costs.
(g) Determination of flood-reduction effects.
(h) Analysis of costs and benefits singly and in combination.

Topographic and layout data are shown on Figures 12 to 15. The general procedure and results of the various phases of the detailed study are summarized in the following paragraphs.

61. Type of Reservoirs Selected. - Consideration was given to the use of two types of flood control reservoirs, namely, the retarding type which operates automatically according to a predetermined plan, and the storage or detention type which can be operated for rate of discharge to fit the requirements of different flood conditions. It was decided to adopt a type of reservoirs combining the advantages of both. Accordingly, the reservoirs were designed with gates to permit flexibility of operation for varying flood conditions and with outlet capacity such that the reservoirs would act as retarding basins if the gates were left open.

62. Outlet Design Floods. - As stated in paragraph 45, Section III, the outlet design floods were based on a three-day storm of 100-year frequency plus a prior, ground-saturating storm of 4.5 inches

in three days. The data for the outlet design floods for all reservoirs is summarized in Table 15. The procedure, for Rumford Reservoir, for example, was to take the computed one-day precipitation of 100-year frequency, 6.0 inches, as the amount of precipitation for the second, or peak, day of a three-day main storm. Applying the ratio of three-day to one-day storms* gives 6.0 times 1.39, or 8.3 inches as the total precipitation for the main storm. This figure is a peak value for the center of a storm and should be reduced to an average for the watershed over which it is to occur. For the net drainage area of 965 square miles above Rumford Reservoir this reduction was determined to be 9%, leaving 7.6 inches as the average over the area. To this was added a prior storm of 4.5 inches, included to insure saturation of the watershed. The total precipitation, 12.1 inches, was reduced by a run-off factor of 90% to 10.85 inches. This volume of run-off was converted into a flood hydrograph by the unit-graph method, applying distribution factors to the selected rainfall for each day of the storm (see paragraph 47, Section III). The construction of the hydrograph for the Rumford Reservoir is illustrated in Table 16. Hydrographs for all reservoirs are shown on Figures 16 to 19.

*This ratio, 1.39 for storms of 100-year frequency, was derived from a general study of computed frequency embracing several New England River basins. The area-reduction factor described in the following sentence was also determined in the general study.

TABLE 15. OUTLET DESIGN FLOODS

(1)	Reservoir	Rumford	Dixfield	Buckfield	Oxford
(2)	Watershed	Androscoggin	Webb	Nezinscot	Little Androscoggin
(3)	Drainage area	*965	125	156	231
(4)	One-day precipitation of 100-year frequency (inches)	6.0	6.0	6.0	6.0
(5)	Three-day precipitation (1.39 times item (4)) (inches)	8.3	8.3	8.3	8.3
(6)	Area reduction factor (%)	9	2	2	2
(7)	Main three-day storm reduced for area (inches)	7.6	8.2	8.2	8.2
(8)	Prior three-day storm (inches)	4.5	4.5	4.5	4.5
(9)	Total precipitation (inches)	12.1	12.7	12.7	12.7
(10)	Total run-off (90% of item (9)) (inches)	10.85	11.45	11.45	11.45
(11)	Total run-off volume (d.s.f.)	281,560	38,480	48,030	71,120
(12)	Total run-off plus base flow (d.s.f.)	313,560	40,080	50,280	75,620
(13)	Item (12) expressed as inches of depth over watershed	12.08	11.92	11.99	12.17
(14)	Peak flow in c.f.s.	76,200	8,000	13,200	14,800
(15)	Peak flow in c.f.s. per square mile	79.0	64.0	84.6	64.1
(16)	Duration of flood in days	16	16	15	18

*Net drainage area after deducting 1095 square miles controlled by Rangeley system of lakes.

TABLE 16. COMPUTATION OF OUTLET DESIGN FLOOD HYDROGRAPH FOR RUMFORD RESERVOIR

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Daily Distribution Factors		Order of Days Run-off	Precipitation of Plan Storm	Run-off, 90% of Rainfall	Total Run-off from Plan Storm	Run-off for Succeeding Days from:						Total Run-off on Succeeding Days from Entire Storm	Total Run-off Plus Base Flow of 2,000 c.f.s.
Day	Per Cent Run-off			(inches)	(d.f.s.)	1st day's rain (d.s.f.)	2nd day's rain (d.s.f.)	3rd day's rain (d.s.f.)	7th day's rain (d.s.f.)	8th day's rain (d.s.f.)	9th day's rain (d.s.f.)	(d.s.f.)	(d.s.f.)
1	10.0	1	1.5	1.35	35,030	3,500						3,500	5,500
2	42.0	2	1.5	1.35	35,030	14,720	3,500					18,220	20,220
3	24.0	3	1.5	1.35	35,030	8,410	14,720	3,500				26,630	28,630
4	12.0	4	0	0	0	4,200	8,410	14,720				27,330	29,330
5	6.0	5	0	0	0	2,100	4,200	8,410				14,710	16,710
6	3.0	6	0	0	0	1,050	2,100	4,200				7,350	9,350
7	2.0	7	0.8	0.70	18,170	700	1,050	2,100	1,820			5,670	7,670
8	1.0	8	6.0	5.40	140,130	350	700	1,050	7,630	14,010		23,740	25,740
		9	0.8	0.70	18,170		350	700	4,360	58,860	1,820	66,090	68,090
		10						350	2,180	33,630	7,630	43,790	45,790
		11							1,090	16,820	4,360	22,270	24,270
		12							550	8,410	2,180	11,140	13,140
		13							360	4,200	1,090	5,650	7,650
		14							180	2,800	550	3,530	5.530
		15								1,400	360	1,760	3,760
		16									180	180	2,180
Totals			12.1	10.85	281,560	35,030	35,030	35,030	18,170	140,130	18,170	281,560	313,560

63. Determination of Reservoir and Outlet Capacities. - The storage capacity of the reservoir and the discharge capacity of the outlets were designed so that the outlet design flood would, with the outlets open, fill the reservoir to the spillway lip. The first step in the determination of the capacities was to make an approximation as to the size of the outlets based on the safe channel capacity downstream from the reservoir. Then, by computing the elevation to which the reservoir would be filled with the assumed outlet discharge and with outlet discharges larger and smaller than this value, a curve was drawn showing the relation between water-surface elevation (or storage capacity) and outlet discharge. The proper reservoir and outlet capacities were then selected. In this study reservoir capacities were selected, whenever possible, equivalent to from five to seven inches of run-off and outlet discharges were kept within the limits of safe channel capacity downstream. In general, it was considered advisable to provide additional gate-controlled outlet capacity for all reservoirs, duplicating the amount required for operation as retarding reservoirs. This provision has been made in order to facilitate passage of floods during the construction period, to permit more rapid emptying of reservoirs after flood danger at downstream points has passed, to provide for a larger range of flexibility in future river regulation and to insure against inability of the reservoir to act as designed should certain outlets be partially blocked or rendered inoperative prior to a flood.

64. Gates. - Although retarding basin operation is feasible for all reservoirs as designed, the installation of gates is proposed in order to provide for additional flood control regulation above that obtainable solely as retarding reservoirs. In addition, this provision will make possible the operation of the reservoirs after the normal flood season for the purpose of augmenting low-water

flows, if such operation is found feasible and is authorized.

65. Spillway Design Floods. - As outlined in paragraph 46, Section III, the spillway design floods were based on a study for the nearby Merrimack Basin, of the most unfavorable meteorological and ground conditions probable. The procedure, using Rumford Reservoir as an example, was to use as a maximum spring storm a value of 10 inches in six days. This amount is slightly greater than that determined in the aforementioned study for the northern sub-watersheds of moderate size in the Merrimack Basin. In order to provide the worst possible conditions, a run-off factor of 100% was assumed. To the total run-off of 10.00 inches there were added six days of snow run-off at the rate of 1.2 inches per day, or a total for six days of 7.2 inches. The total run-off thus estimated as the worst probable was then increased by 50% in accordance with the departmental policy of designing spillways capable of passing safely 50% in excess of the estimated worst probable flows (R. & H. No. 39, 1936). The total run-off of 25.80 inches was converted into a flood hydrograph by the unit-graph method using the same distribution factors as for the outlet design flood described in paragraph 62. If the design flood hydrograph showed a peak discharge value less than the product of 4,000 and the square root of the drainage area ($Q = 4{,}000\sqrt{D.A.}$), the hydrograph was revised to obtain a peak flow of this value, but the total volume of run-off from the storm was not changed. The data for the spillway design floods for all reservoirs studied are summarized in Table 17. The construction of the hydrograph for the Rumford Reservoir is illustrated in Table 18.

TABLE 17. SPILLWAY DESIGN FLOODS

(1)	Reservoir	Rumford	Dixfield	Buckfield	Oxford
(2)	Watershed	Andros-coggin	Webb	Nezinscot	Little Andros-coggin
(3)	Drainage area (sq.mi.)	*965	125	156	231
(4)	Precipitation for maximum spring storm of 6 days (inches)	10.00	10.00	10.00	10.00
(5)	Total snow melt (inches)	7.20	7.20	7.20	7.20
(6)	Run-off (inches) 100% of items (4) and (5)	17.20	17.20	17.20	17.20
(7)	Total run-off (inches) item (6) plus 50% factor of safety	25.80	25.80	25.80	25.80
(8)	Total run-off (d.s.f.)	669,460	86,670	108,232	160,160
(9)	Total run-off plus base flow (d.s.f.)	682,460	88,295	110,150	163,610
(10)	Item (9) in inches depth over watershed	26.30	26.27	26.26	26.34
(11)	Instantaneous peak flow (c.f.s.)	180,000	44,720	49,960	60,790
(12)	Value of c in formula $Q = c\sqrt{D.A.}$	5,794	4,000	4,000	4,000
(13)	Instantaneous peak flow in c.f.s. per square mile	187	358	320	263
(14)	Duration of flood in days	13	13	12	15

*Net drainage area after deducting 1095 square miles controlled by Rangeley system of lakes.

TABLE 18. COMPUTATION OF SPILLWAY DESIGN FLOOD HYDROGRAPH FOR RUMFORD RESERVOIR

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Daily Distribution Factors		Order of Days Run-off	Rainfall (inches)	Snow Melt (inches)	Run-off from Rain and Snow (inches)	Total Run-off Including 50% Increase (inches)	Total Run-off (d.s.f.)	Run-off for Succeeding Days from:						Total Run-off on Succeeding Days from Rain & Snow (d.s.f.)	Total Run-off Plus a Base Flow of 1,000 d.s.f. (d.s.f.)
Day	Per Cent Run-off							1st day's Rain and Snow (d.s.f.)	2d day's Rain and Snow (d.s.f.)	3d day's Rain and Snow (d.s.f)	4th day's Rain and Snow (d.s.f.)	5th day's Rain and Snow (d.s.f.)	6th day's Rain and Snow (d.s.f.)		
1	10.0	1	0.35	1.20	1.55	2.33	60,460	6,050						6,050	7,050
2	42.0	2	0.45	1.20	1.65	2.47	64,090	25,390	6,410					31,800	32,800
3	24.0	3	1.10	1.20	2.30	3.45	89,520	14,510	26,920	8,950				50,380	51,380
4	12.0	4	2.00	1.20	3.20	4.80	124,550	7,260	15,380	37,600	12,460			72,700	73,700
5	6.0	5	5.50	1.20	6.70	10.05	260,780	3,630	7,690	21,480	52,310	26,080		111,190	112,190
6	3.0	6	0.60	1.20	1.80	2.70	70,060	1,810	3,850	10,740	29,890	109,530	7,010	162,830	163,830
7	2.0	7						1,210	1,920	5,370	14,950	62,590	29,430	115,470	116,470
8	1.0	8						600	1,280	2,690	7,470	31,290	16,810	60,140	61,140
		9							640	1,790	3,740	15,650	8,410	30,230	31,230
		10								900	2,490	7,820	4,200	15,410	16,410
		11									1,240	5,210	2,100	8,550	9,550
		12										2,610	1,400	4,010	5,010
		13											700	700	1,700
Totals	100		10.00	7.20	17.20	25.80	669,460	60,460	64,090	89,520	124,550	260,780	70,060	669,460	682,460

66. Determination of Spillway Capacities. - The general criterion adopted for the design of spillways was that each spillway should be able to pass safely 50% in excess of the estimated worst probable flood (the spillway design flood) assuming all outlets blocked and the water surface at the elevation of the spillway crest at the beginning of the flood. The spillway crest elevation was selected as described in paragraph 63 and a type of spillway was chosen to fi the physical conditions at the dam site. The discharge characteristics of the spillway were then determined by routing the spillway design flood through the reservoir for several assumed lengths of spillway. The maximum water surface elevations attained were plotted against the spillway lengths, thus giving a relation between the heights of dam required for various lengths of spillway. Then, within the physical limits on length of spillway imposed by conditions at the dam site, a length was selected such that the cost of any increase or decrease in length of spillway would be balanced by the cost of the corresponding decrease or increase in height of dam.

67. Provision of Freeboard. - The amount of freeboard provided for earth dams and dikes was determined in accordance with the provisions outlined in the departmental Engineer Bulletin No. 2, 1937. The freeboard provided is sufficient to allow for the requirements of possible wave action in the reservoir at the maximum water surface as determined by the spillway design flood under the conditions described in the preceding paragraph. The requirements for wave action were based on Stevenson's formula for the height of waves as shown in Table 19, following. The allowance for ride-up of waves on the sloped surface of the dam was made by making the total freeboard required above the still-water level equal to 1.4 times the total height of the wave from crest to

trough as computed by Stevenson's formula. The data used in determining freeboard requirements, together with the actual freeboard provided at each dam, are listed in Table 19, following.

TABLE 19. FREEBOARD FOR EARTH DAMS

Reservoir	Maximum Fetch (Statute miles)	Fetch "f" (Nautical miles)	Wave Height "H" * (feet)	Freeboard Required for Wave Action** (feet)	Maximum Water Surface in Reservoir (feet-M.S.L.)	Elev. of Top of Dam (feet-M.S.L.)	Freeboard Provided (feet)
Rumford	2.8	2.4	3.59	5.0	670.0	675	5.0
Dixfield	6.0	5.2	4.41	6.2	462.4	469	6.6
Buckfield	1.5	1.3	3.14	4.4	357.7	363	5.3
Oxford	4.0	3.5	3.94	5.5	336.0	342	6.0

* By Stevenson's Formula, $H = 1.5 \sqrt{f} + (2.5 - \sqrt[4]{f})$
** Freeboard = 1.4 H

68. Extent of Investigation of Reservoir Areas and Dam Sites. - The field investigations of the four reservoirs selected for detailed study consisted of topographic surveys of the reservoir area and dam site, a property appraisal survey, geological reconnaissance, and determination of the character of materials available for construction. Topographic surveys in the reservoir areas were conducted to develop contours at five-foot intervals, principally to provide data for accurate area-capacity curves. These are shown, together with topographic details, on Figures 12 to 15. At the dam sites, contours were developed at one or two-foot intervals. Foundation and overburden conditions and the character of materials available for construction were determined by geological reconnaissance. Suitable materials are available for concrete aggregates and for either hydraulic placement or rolled-fill construction with rock shell.

69. Estimated Costs of Reservoirs. - Estimates of the cost of the reservoirs studied were based on the preliminary designs shown on Figures 12 to 15. Data for the estimates of cost of lands and rights-of-way in the reservoir areas were obtained in the topographic and property appraisal surveys. Descriptions and details of the estimates of cost are given in Tables 20 to 27 following.

TABLE 20. RUMFORD RESERVOIR

(See Figure 12)

Drainage Area: 965 square miles (net).

Capacity: 295,000 acre-feet; 5.7 inches run-off.

Reservoir Area: 15,200 acres at Spillway-Crest Elevation 655 ft. M.S.L.

Dam: Earth Maximum Height: 90 feet

Overall Length: 1450 feet. Length of Spillway: 750 feet

Bedrock is not available under the dam or spillway. The dam is of earth fill, 35 feet wide at the top (elevation 675 ft.) with side slopes of 1 on 3. The upstream face and toe are of riprap. The spillway, located 12,000 feet northwest of the dam, consists of a hollow concrete overflow section 750 feet long with earth-fill retaining sections 430 feet long. Two 22-foot diameter outlet tunnels 1100 feet long pass through the hill on the south side of the dam. The outlets are controlled by six 8 x 16-1/2 foot sliding gates.

Land involved: 17,000 acres Railroads affected: 7 miles

Towns affected: Rumford Center, Hanover, Newry, Bethel, No. Bethel, W. Bethel Highways affected: 33 miles

Estimated First Cost (including engineering, administration, superintendence and contingencies)

Land and relocation costs		
Land and buildings	$2,235,000	
Relocation railroads	837,000	
Relocation highways, bridges, etc	2,430,000	
Other relocations	433,000	
Total, land and relocation costs		$5,935,000
Construction costs		
Dams and appurtenances		5,227,000
Total, all costs		$11,162,000

Cost per acre-foot of storage $37.84 Cost per square mile of drainage area $ 11,567

TABLE 21. COST ESTIMATE - RUMFORD RESERVOIR

I. CONSTRUCTION COSTS

(a) DAM, SPILLWAY & OUTLETS

	Quantity		Unit Cost	Cost
Stream Diversion		lump sum	$	$200,000
Dam Site Clearing	60	acres	150.00	9,000
Earth Excavation - Structures	1,126,000	cubic yards	.25	281,500
Earth Excavation - Spillway	86,000	cubic yards	.30	25,800
Rock Excavation - Structures	175,000	cubic yards	2.00	350,000
Rock Excavation - Tunnels	49,500	cubic yards	8.00	396,000
Drilling & Grouting	4,000	linear feet	10.00	40,000
Cut-Off - Steel Sheet Piling	54,800	square feet	1.25	68,500
Concrete - Hollow Dam	18,100	cubic yards	20.00	362,000
Concrete - Outlets & Tunnels .	38,600	cubic yards	14.00	540,000
Concrete - Mass	18,700	cubic yards	12.00	224,400
Reinforcement	2,260	tons	120.00	271,200
Embankment - Earth fill . .	980,000	cubic yards	.50	490,000
Gates & Operating Devices .		lump sum		160,000
Miscellaneous Steel		lump sum		20,000
Gate House Superstructure . .	84,000	cubic feet	.80	67,200
Service Power Lines	6	miles	3,000.00	18,000
Service Roads		lump sum		3,000
Operator's Quarters		lump sum		5,000
TOTAL - DAM, SPILLWAY & OUTLETS				$3,532,000
(b) RESERVOIR CLEARING		lump sum		340,000
SUB-TOTAL - CONSTRUCTION COSTS				$3,872,000
(c) Eng'ring, Inspec., Overhead & Contingencies			35%	1,355,000
TOTAL CONSTRUCTION COST				$5,227,000

II. DAMAGES

	Quantity		Unit Cost	Cost
(a) Land to Elev. 665	17,000	acres	$ 45.00	$ 765,000
(b) Buildings to Elev. 655 . .		lump sum		850,000
(c) Cemetery Relocation . . .	1,740	graves	50.00	87,000
(d) Power Privileges Destroyed	1,000	H. P.	40.00	40,000
(e) Railroad Relocation . . .	7	miles	88,570.00	620,000
(f) Highway Relocation	33	miles	54,500.00	1,800,000
(g) Telephone Line Relocation .	40	miles	4,000.00	160,000
(h) Telegraph Line Relocation .	7	miles	2,000.00	14,000
(i) Power Line Relocation . . .	20	miles	3,000.00	60,000
SUB-TOTAL - DAMAGES				$4,396,000
(j) Eng'ring, Appraisals, Overhead & Contingencies			35%	1,539,000
TOTAL DAMAGES				$5,935,000

TOTAL ESTIMATED FIRST COST	$11,162,000
Estimated Cost Per Acre-Foot of Storage	$ 37.84
Estimated Cost Per Square Mile of Drainage Area	$ 11,567

TABLE 22. DIXFIELD RESERVOIR

(See Figure 13)

Drainage Area: 125 square miles

Capacity: 40,300 acre-feet; 6.0 inches run-off

Reservoir Area: 2,500 acres at Spillway-Crest Elevation 450 ft. M.S.L.

Dam: Earth and Concrete — Maximum Height: 60 ft.

Overall Length: 2140 feet. — Length of Earth Section 1,880 ft.

Length of Concrete Section: 260 ft. (including spillway 200 ft. long)

Bedrock is not available at the dam site. The spillway consists of a hollow concrete overflow section. The outlet structures, adjacent to the spillway, consist of four concrete box outlets each 3 ft. 9 in. by 7 ft. controlled by four vertical sliding gates 3ft. 9 in. by 7 ft. The retaining section of the dam is of earth fill, 25 feet wide at the top (elevation 469 feet) with side slopes of 1 on 3. The upstream face is riprapped and a rock fill toe provided downstream.

Land involved: 3,000 acres — Railroads affected: none

Towns affected: Carthage — Highways affected: 0.7 mile

Estimated First Cost (including engineering, administration, superintendence and contingencies)

<u>Land and relocation costs</u>		
Land and buildings	$151,000	
Relocation highways, bridges, etc.	47,000	
Other relocations	41,000	
Total, land and relocation costs		$ 239,000
<u>Construction costs</u>		
Dams and appurtenances		659,000
Total, all costs		$ 898,000

Cost per acre-foot of storage $22.28 — Cost per square mile of drainage area $ 7,184

TABLE 23. COST ESTIMATE - DIXFIELD RESERVOIR

I. CONSTRUCTION COSTS

(a) DAM, SPILLWAY & OUTLETS

	Quantity	Unit Cost	Cost
Stream Diversion	lump sum	$	$ 15,000
Dam Site Clearing	7 acres	150.00	1,050
Earth Excavation - Structures) Earth Excavation - Spillway)	64,000 cubic yards	.50	32,000
Cut-Off - Steel Sheet Piling . .	15,000 square feet	1.75	26,250
Concrete - Hollow Dam	2,700 cubic yards	20.00	54,000
Concrete - Outlets	6,000 cubic yards	20.00	120,000
Reinforcement	350 tons	120.00	42,000
Embankment - Earth fill	106,000 cubic yards	.60	63,600
Gates & Operating Devices . . .	lump sum		25,000
Miscellaneous Steel	lump sum		8,600
Gate House Superstructure . . .	19,000 cubic feet	1.50	28,500
Service Power Lines	lump sum		4,000
Service Roads	lump sum		3,000
Operator's Quarters	lump sum		5,000
TOTAL - DAM, SPILLWAY & OUTLETS			$ 428,000
(b) RESERVOIR CLEARING	lump sum		60,000
SUB-TOTAL - CONSTRUCTION COSTS			$ 488,000
(c) Eng'ring, Inspec., Overhead & Contingencies 35%			171,000
TOTAL CONSTRUCTION COST			$ 659,000

II. DAMAGES

	Quantity	Unit Cost	Cost
(a) Land to Elev. 460	3,000 acres	$ 20.00	$ 60,000
(b) Buildings to Elev. 450 . . .	lump sum		50,000
(c) Power Privileges Destroyed .	50 H.P.	40.00	2,000
(d) Highway Relocation	0.7 mile	50,000.00	35,000
(e) Telephone Line Relocation . .	6 miles	2,500.00	15,000
(f) Power Line Relocation	5 miles	3,000.00	15,000
SUB-TOTAL - DAMAGES			$ 177,000
(g) Eng'ring, Appraisals, Overhead & Contingencies 35%			62,000
TOTAL DAMAGES			$ 239,000

TOTAL ESTIMATED FIRST COST	$ 898,000
Estimated Cost Per Acre-Foot of Storage	$ 22.28
Estimated Cost Per Square Mile of Drainage Area	$ 7,184

TABLE 24. BUCKFIELD RESERVOIR

(See Figure 14)

Drainage Area: 156 square miles

Capacity: 49,200 acre-feet; 5.9 inches run-off

Reservoir Area: 4,050 acres at Spillway-Crest Elevation 345 ft. M.S.L.

Dam: Earth — Maximum Height: 68 feet

Overall Length: 2100 feet — Length of Spillway: 250 feet

The outlet structures and the channel spillway rest on bedrock. The dam is of earth fill 30 feet wide at the top (elevation 363 ft.) with side slopes of 1 on 3. The upstream face is riprapped and a rock filled toe provided downstream. The spillway consists of a channel cut through earth and rock at the north end of the dam. The outlet structures consist of one 12-foot diameter semi-elliptical conduit controlled by four 4-foot by 8-foot sliding gates. In addition to the dam there are four earth dikes having a total length of 4500 feet.

Land involved: 5,600 acres — Railroads affected: None

Towns affected: None — Highways affected: 5-1/2 miles

Estimated First Cost (including engineering, administration, superintendence and contingencies)

Land and relocation costs		
Land and buildings	$324,000	
Relocation highways, bridges, etc.	432,000	
Other relocations	34,000	
Total, land and relocation costs		$ 790,000
Construction costs		
Dams and appurtenances		1,251,000
Total, all costs		$2,041,000

Cost per acre-foot of storage $41.48 — Cost per square mile of drainage area $ 13,083

TABLE 25. COST ESTIMATE - BUCKFIELD RESERVOIR

I. CONSTRUCTION COSTS

(a) DAM, SPILLWAY & OUTLETS

	Quantity	Unit Cost	Cost
Stream Diversion	lump sum	$	$ 30,000
Dam Site Clearing	50 acres	150.00	7,500
Earth Excavation - Structures . .	120,000 cubic yards	.30	36,000
Earth Excavation - Dikes	24,000 cubic yards	.30	7,200
Rock Excavation - Structures . .	4,000 cubic yards	3.00	12,000
Rock Excavation - Spillway . . .	110,000 cubic yards	2.00	220,000
Drilling and Grouting	1,200 linear feet	10.00	12,000
Cut-Off - Concrete Key	830 cubic yards	12.00	9,960
Concrete - Mass	2,200 cubic yards	12.00	26,400
Concrete - Outlets	5,800 cubic yards	15.00	87,000
Reinforcement	230 tons	120.00	27,600
Embankment - Earth fill	520,000 cubic yards	.50	260,000
Gates & Operating Devices . . .	lump sum		27,000
Miscellaneous Steel	lump sum		10,840
Gate House Superstructure . . .	13,000 cubic feet	1.50	19,500
Service Power Lines	lump sum		5,000
Service Roads	lump sum		12,000
Operator's Quarters	lump sum		5,000
TOTAL - DAM, SPILLWAY & OUTLETS			$ 815,000
(b) RESERVOIR CLEARING	lump sum		112,000
SUB-TOTAL - CONSTRUCTION COSTS			$ 927,000
(c) Eng'ring, Inspec., Overhead & Contingencies 35%			324,000
TOTAL CONSTRUCTION COST			$1,251,000

II. DAMAGES

	Quantity	Unit Cost	Cost
(a) Land to Elev. 355	5,600 acres	$ 25.00	$ 140,000
(b) Buildings to Elev. 345	lump sum		80,000
(c) Cemetery Relocation	200 graves	50.00	10,000
(d) Power Privileges Destroyed . .	500 H.P.	40.00	20,000
(e) Highway Relocation	$5\frac{1}{2}$ miles	58,200.00	320,000
(f) Telephone Line Relocation . .	4 miles	2,500.00	10,000
(g) Power Line Relocation	lump sum		5,000
SUB-TOTAL - DAMAGES			$ 585,000
(h) Eng'ring, Appraisals, Overhead & Contingencies 35%			205,000
TOTAL DAMAGES			$ 790,000

TOTAL ESTIMATED FIRST COST	$2,041,000
Estimated Cost Per Acre-Foot of Storage	$ 41.48
Estimated Cost Per Square Mile of Drainage Area	$ 13,083

TABLE 26. OXFORD RESERVOIR

(See Figure 15)

Drainage Area: 231 square miles

Capacity: 92,000 acre-feet; 7.5 inches run-off

Reservoir Area: 6,100 acres at Spillway-Crest Elevation 325 ft. M.S.L.

Dam: Earth and Concrete Maximum Height: 67 ft.

Overall Length: 1,155 ft. Length of Earth Section: 820 ft.

Length of Concrete Section: 335 ft. (including 240 ft. spillway)

Bedrock is exposed in the present river channel where the concrete spillway and outlet structures are located. The spillway section consists of a gravity-type Ogee section. The outlet structures consist of four 4 ft. by 6 ft. 3 in. box conduits controlled by four sliding gates, each 4 ft. by 6 ft. 3 in. located in a control tower at one end of the spillway. The remainder of the dam is of earth fill 35 ft. wide at the top (elevation 342 feet) and with 1 on 3 side slopes. The upstream face is riprapped and a rock fill toe provided downstream. In addition to the main dam there are two earth dikes totalling 7,100 feet in length.

Land involved: 7,000 acres Railroads affected: 3-3/4 miles

Towns affected: Oxford, Welchville Highways affected: 8 miles

Estimated First Cost (including engineering, administration, superintendence and contingencies)

<u>Land and relocation costs</u>		
Land and buildings	$ 763,000	
Relocation railroads	613,000	
Relocation highways, bridges, etc.	513,000	
Other relocations	81,000	
Total, land and relocation costs		$1,970,000
<u>Construction costs</u>		
Dams and appurtenances		1,724,000
Total, all costs		$3,694,000

Cost per acre-foot of storage $40.15 Cost per square mile of drainage area $ 15,991

TABLE 27. COST ESTIMATE - OXFORD RESERVOIR

I. CONSTRUCTION COSTS

(a) DAM, SPILLWAY & OUTLETS

	Quantity		Unit Cost	Cost
Stream Diversion		lump sum	$	$ 25,000
Dam Site Clearing	40	acres	150.00	6,000
Earth Excavation - Structures . .	40,000	cubic yards	.30	12,000
Earth Excavation - Dikes	100,000	cubic yards	.30	30,000
Rock Excavation - Structures . .	3,900	cubic yards	3.00	11,700
Drilling and Grouting	1,300	linear feet	10.00	13,000
Cut-Off - Concrete Key	85	cubic yards	14.00	1,190
Concrete - Wing Walls	24,800	cubic yards	15.00	372,000
Concrete - Outlets	2,900	cubic yards	15.00	43,500
Concrete - Mass	10,500	cubic yards	12.00	126,000
Reinforcement	1,100	tons	120.00	132,000
Embankment and Dikes - Earth fill	475,000	cubic yards	.60	285,000
Gates & Operating Devices		lump sum		30,000
Miscellaneous Steel		lump sum		10,160
Gate House Superstructure	18,300	cubic feet	1.50	27,450
Service Power Lines		lump sum		4,000
Service Roads		lump sum		3,000
Operator's Quarters		lump sum		5,000
TOTAL - DAM, SPILLWAY & OUTLETS				$1,137,000
(b) RESERVOIR CLEARING		lump sum		140,000
SUB-TOTAL - CONSTRUCTION COSTS				$1,277,000
(c) Eng'ring, Inspec., Overhead & Contingencies			35%	447,000
TOTAL CONSTRUCTION COST				$1,724,000

II. DAMAGES

(a) Land to Elev. 335	7,000	acres	$ 45.00	$ 315,000
(b) Buildings to Elev. 325		lump sum		240,000
(c) Cemetery Relocation	400	graves	50.00	20,000
(d) Power Privileges Destroyed . .	250	H.P.	40.00	10,000
(e) Railroad Relocation	3-3/4	miles	121,000.00	454,000
(f) Highway Relocation	8	miles	47,500.00	380,000
(g) Telephone Line Relocation . .	6	miles	3,000.00	18,000
(h) Telegraph Line Relocation . .	3-3/4	miles	1,870.00	7,000
(i) Power Line Relocation	5	miles	3,000.00	15,000
SUB-TOTAL - DAMAGES				$1,459,000
(j) Eng'ring, Appraisals, Overhead & Contingencies			35%	511,000
TOTAL DAMAGES				$1,970,000

TOTAL ESTIMATED FIRST COST	$3,694,000
Estimated Cost Per Acre-Foot of Storage	$ 40.15
Estimated Cost Per Square Mile of Drainage Area	$ 15,991

70. <u>Calculation of Annual Carrying Charges</u>. - A calculation of the economic cost or annual carrying charges has also been made for use in the economic analyses of the reservoirs. It is pointed out that this calculation of carrying charges, which is shown for the separate reservoirs in Table 28, following, is for the purpose of economic analysis only, and is not intended to represent the actual arrangement of carrying charges which may be used in practice. It does, however, represent a summation of all the annual charges against the reservoirs which must be justified by the benefits to be received. The standard interest rate of $3\frac{1}{2}$ per cent for Federal investments has been used. The allowances for amortization of obsolescence and depreciation, based on a 25-year life for movable parts and a 50-year life for fixed parts, automatically cover the cost of major repairs because such items of repair will generally extend the life of the structure. The annual expense of an operator and minor items of maintenance, such as painting and minor repairs, are included in the allowances for operation and maintenance (Item b(3) in Table 28). Item b(4) in Table 28 represents an estimate of the net loss in taxes. Some return on land and property acquired for the project may be expected, particularly on that which lies near the upper limits of the reservoir areas, which will be flooded very infrequently, and, in any case, rarely in the growing season, thereby permitting the farming of lands normally used for that purpose.

TABLE 28. ANNUAL COST OF FLOOD-CONTROL RESERVOIRS

Item	Rumford	Dixfield	Buckfield	Oxford
Construction Period	2 Years	2 Years	2 Years	2 Years
a. Federal Investment				
1. Cost of construction, lands and damages	$ 11,162,000	$ 898,000	$ 2,041,000	$ 3,694,000
2. 3% interest on (a-1) during 1/2 construction period	334,860	26,940	61,230	110,820
3. Total Federal Investment	$ 11,496,860	$ 924,940	$ 2,102,230	$ 3,804,820
4. Fixed parts	11,229,860	870,740	2,051,630	3,744,420
5. Movable parts	267,000	54,200	50,600	60,400
b. Federal Annual Carrying Charge				
1. $3\frac{1}{2}$% interest on a-3	$ 402,390	$ 32,370	$ 73,580	$ 133,170
2. Amortization - fixed parts at .763% of a-4	85,680	6,640	15,650	28,570
- movable parts at 2.567% of a-5	6,850	1,390	1,300	1,550
3. Operation and maintenance	10,080	5,000	6,070	6,510
4. Loss of taxes on land	17,000	3,000	5,600	7,000
c. Total Annual Carrying Charge	$ 522,000	$ 48,400	$ 102,200	$ 176,800

Amortization of Obsolescence and Depreciation on the following basis:
Fixed Parts - 0.763% annually (50-year life - $3\frac{1}{2}$% interest)
Movable Parts - 2.567% annually (25-year life - $3\frac{1}{2}$% interest)

71. <u>Effects of Reservoirs on Past and Plan Floods.</u> - The effectiveness of the flood control reservoirs in reducing flood stages at four principal damage centers for a flood similar to that of March, 1936 is shown in Table 29, following. Natural and modified hydrographs of the March, 1936 flood at the reservoir sites are shown on Figures 20 to 23. The reductions in stage and discharge at the damage centers of Rumford, Livermore Falls, Lewiston, Auburn and Lisbon Falls are shown on Figures 24 to 28. A natural and modified profile is shown on Figures 29 and 30.

TABLE 29. APPROXIMATE REDUCTIONS IN STAGE AND DISCHARGE AT SEVERAL STATIONS FOR A FLOOD SIMILAR TO THAT OF MARCH, 1936

Station	Drainage Area above Sq. Mi.	Reservoirs above Station	Drainage Area under Control		Discharge c.f.s.			Stage in Feet		Net Reduction
			Sq. Mi.	Per Cent	Natural Flow	Modified Flow	Per Cent Reduction	Recorded	Modified	
Rumford, Me. (On main stem of Androscoggin River)	995*	Rumford	965	97	74,000	36,300	50.9	612**	607.4**	4.6
Livermore Falls, Me. (On main stem of Androscoggin River)		Rumford	965	70.7	94,000	57,500	38.8	11.1***	9.0***	2.1
	1356*	Rumford and Dixfield	1090	80.5	94,000	49,500	47.3	11.1***	8.6***	2.5
Lewiston, Me. (On main stem of Androscoggin River)		Rumford	965	55.1	118,000	83,800	29.0	264.5**	261.3**	3.2
	1752*	Rumford, Dixfield and Buckfield	1246	71.1	118,000	65,000	44.9	264.5**	259.5**	5.0
Auburn, Me. (At mouth of Little Androscoggin River)	380	Oxford	231	60.9	23,700	12,700	46.4	141.9**	126.7**	15.2
Lisbon Falls, Me. (On main stem of Androscoggin River)		Rumford	965	41.9	155,000	123,000	20.7	12.3***	10.7***	1.6
		Rumford, Dixfield, Buckfield and Oxford	1477	64.1	155,000	98,500	36.5	12.3***	9.5***	2.8
	2305*	Rumford, Dixfield and Buckfield	1246	54.1	155,000	113,000	27.1	12.3***	10.3***	2.0

* Net drainage area (drainage area above Errol Dam (1095 sq. mi.) not included).

** U.S.G.S. Datum *** Local Datum

72. <u>Annual Benefits from Flood Control Reservoirs.</u> - The reductions in stage afforded by the various reservoirs and combinations of reservoirs have been translated into annual flood-prevention benefits on the basis of computed expectancy of the increments of stage reduction. By this method the amounts of damage occurring in one or two-foot increments of stage are multiplied by the annual expectancy of each increment of stage up to the maximum and the sum of the resulting incremental losses is the total annual loss to be expected. The difference between expected losses with and without control is the annual benefit to that control. The annual losses in each reach are shown on Figures 32, 34, 36 and 38. A comparison of the annual benefits and costs is given in Table 30, following.

TABLE 30. COMPARISON OF ANNUAL CARRYING CHARGES AND FLOOD CONTROL BENEFITS

Reservoirs	Total First Cost	Annual Carrying Charges	Annual Flood-Control Benefits	Ratio of Annual Benefits to Annual Charges
Four (R-D-B-O)*	$17,795,000	$ 849,400	$ 374,100	0.44
Three (R-D-B)**	14,101,000	672,600	359,200	0.53
Rumford alone	11,162,000	522,000	322,700	0.62

* Rumford, Dixfield, Buckfield and Oxford
** Rumford, Dixfield and Buckfield

73. <u>Levees and River Walls.</u> - Flood protection by means of levees or river walls has a certain advantage in that it is positive up to the height of levee or river wall provided plus any additional height which may be added by sand-bagging or other emergency operations immediately preceding or during a flood. The protection afforded, however, is local in extent rather than general, as in the case of reservoirs. There are no incidental benefits such as those which may accrue from reservoir control. The provision of flood protection by construction of levees and river walls in the principal damage centers of the valley has been investigated with a view to determining

the feasibility of this method as a primary means of flood control. The first step in the study was to examine the flood damage statistics in the basin with a view to segregating those areas in which flood damages were confined to a reasonably concentrated section and where local flood protection might prove to be economically justified. This preliminary examination revealed 11 communities which appeared to offer some possibilities for flood protection by levees and river walls. These cities and towns are listed in Table 31, together with the amounts of damage sustained during the March, 1936 flood. Field reconnaissance of these communities and further examination of the damage statistics were sufficient to establish the fact that local flood protection would not be economically justified at seven of these damage centers. The remaining four communities (Rumford, Mexico, Auburn and Lewiston) were selected for detailed study of flood protection possibilities and analysis of costs and benefits.

TABLE 31. SUMMARY OF FLOOD DAMAGES AT PRINCIPAL DAMAGE CENTERS

Damage Center	Damage Reported		Estimated additional	Total	Principal Damages
	Direct	Indirect	Indirect		
Brunswick	$ 81,600	$ 3,000	$ 3,000	$ 87,600	Commercial
Topsham	42,900	35,100	35,100	113,100	Commercial
Lisbon Falls	12,700	22,500	22,500	57,700	Commercial
Auburn	216,850	135,000	135,000	486,850	Industrial, Commercial and Residential
Lewiston	138,450	12,550	12,550	163,550	Industrial, Commercial and Residential
Chisholm	11,500	-	-	11,500	Commercial
Livermore Falls	17,300	9,500	9,500	36,300	Commercial and Residential
Rumford	145,100	750	750	146,600	Commercial and Residential
Mexico	43,750	1,250	1,250	46,250	Commercial and Residential
Virginia	31,530	1,700	1,700	34,930	Commercial and Residential
Berlin	26,550	2,500	2,500	31,550	Commercial and Residential
Total	$768,230	$223,850	$223,850	$1,215,930	

74. Extent of Investigation. - Enlarged aerial photographs were used as base sheets for the topographic surveys. Preliminary designs were then prepared, as shown on Figures 39 and 40. Earth levees and concrete walls constitute the principal protective works. Levees were designed with 1 on 3 side slopes, including riprap protection on the river slope and with steel sheet piling cut-off walls for heights in excess of 15 feet. Concrete walls in general were proportioned as gravity structures founded on bearing piles with sheet piling cut-off. Where mill buildings line the waterfront, a semi-gravity type of wall joined with the existing rubble foundations of the buildings was adopted as the basis for determining costs. The crest elevation for flood walls was established at the level of the 1936 flood with provision in the design for withholding two feet of additional stage by flashboards. Tops of levees were set at three feet above the 1936 flood level. This additional height, with some emergency work for safety against wave-washing on the crest, was considered to constitute dependable protection against floods having a crest two feet higher than in 1936. Costs of necessary sewerage and pumping stations for the areas protected were included in the estimates. Sizes of sewers and pumps were roughly proportioned to handle a storm run-off of one-quarter inch per hour over the watershed of the protected areas plus nominal allowances for infiltration and domestic sewage.

75. Determination of Annual Costs and Benefits. - For the purposes of economic analysis the annual costs, or carrying charges, were based on the standard interest rate of 3-1/2% for Federal investments for all items of cost. Amortization was based on 50-year life for all items except sewers and pumping stations (designated as "Drainage" in Table 32), for which a 30-year life was used. Benefits were determined by separating the damages

in the areas affected from the basic damage statistics described in Section IV and applying the same methods of computing annual losses and benefits as illustrated in Section IV. Pertinent data for the communities analyzed for possibilities of levees and river walls as the primary means of obtaining flood control are summarized in Table 32.

TABLE 32. LEVEES AND RIVER WALLS AS THE PRIMARY MEANS OF FLOOD CONTROL

Location	Auburn A	Auburn B	Auburn C	Lewiston D	Lewiston E	Rumford incl. Channel Improv't	Mexico	Rumford Mexico Combined
Area Protected (acres)	5.4	8.1	12.0	18.8	16.0	22.6	19.4	42.0
Length of Protection in feet	390	1,330	1,750	2,400	3,900	1,440	2,370	3,810
Principal damages	Ind.	Ind., Com. & Res.	Res. & Com.	Ind., Com. & Res.	Ind., Com. & Res.	Ind.	Res.	Ind. & Res.
Damages 1936 Flood								
Direct	$ 18,150	$107,650	$ 35,700	$ 52,550	$ 84,750	$145,100	$ 83,450	$228,550
Indirect	22,000	142,100	13,400	7,700	17,400	1,500	2,500	4,000
Ratio of Indirect to Direct	1.21	1.32	0.38	0.15	0.20	0.01	0.03	0.02
Total	$ 40,150	$249,750	$ 49,100	$ 60,250	$102,150	$146,600	$ 85,950	$232,550
Cost of Protection								
Levees and Walls	$ 44,330	$227,400	$115,500	$302,000	$260,500	$115,900	$ 85,850	$201,750
Drainage	26,000	139,400	101,700	189,000	236,300	68,300	133,350	201,650
Property	800	58,000	3,200	27,000	42,000	1,200	20,200	21,400
Other Costs	270	9,200	17,200	27,000	58,200	*123,600	3,400	126,000
Total Costs	$ 71,400	$434,000	$237,600	$545,000	$597,000	$309,000	$242,800	$550,800
Economic Analysis								
Annual Costs	$ 4,670	$ 21,490	$ 11,560	$ 26,070	$ 30,400	$ 14,820	$ 13,110	$ 27,930
Annual Benefits	$ 2,500	$ 15,650	$ 3,100	$ 3,770	$ 6,400	$ 10,650	$ 6,200	16,850
Ratio of Benefits to Costs	.54	.73	.27	.14	.21	.72	.47	.60

* Including channel excavation and jetty as shown on Figure 40.

76. Channel Improvements. - Some degree of reduction of flood losses can be effected by reconstruction or removal of dams, bridges and buildings which form artificial obstructions to flood flows. Such improvements generally can be undertaken economically only when the structure has reached the end of its economic or physical life, or when extensive reconstruction is required for some purpose other than flood control alone. Specific suggestions concerning desirable improvements to be incorporated in plans for reconstruction of existing structures, when undertaken for reasons other than for flood control, are listed below by localities. None of these would lessen flood damages to a sufficient degree to warrant its prosecution, at the present time, for flood control purposes alone.

a. Berlin - High-water elevations are controlled by a series of 5 dams in the city. The stream is further obstructed by bends, gorges, ledges, and mill buildings. In addition to the losses caused by the main stream, the Dead River, a small tributary running through the city, caused considerable damage by overflowing its banks. The Brown Company, whose buildings line both river banks down to Mason Street, has considered a program of channel improvement and protection within the limits of its flowage rights. The buildings of the International Paper Company below the Mason Street bridge are being razed. This work should improve flow conditions through that reach. It is suggested that the following additional improvements will be of benefit: Raise the highway bridge above the "Sawmill" dam, raise and lengthen that portion of the Mason Street bridge below the dam spillway; raise and lengthen the railway bridge, and eliminate the encroachment of the approach fill on the right bank; remove a portion of the high ledge splitting the flood channel below the Mason Street bridge. The Dead River, running through the City of Berlin, should be improved where feasible by deepening and widening. For the 1200 feet of its length above the mouth, encroachments along the banks necessitate use of a pressure conduit to obtain adequate discharge capacity. The alternative method of reducing severe flood flows would be the construction of a reservoir with about 2500 acre feet of flood storage at the site of the old Brown Company dam above the city. The channel improvement with pressure conduit will afford the more economical means of flood protection because of the fact that the reservoir would necessitate construction of a dike for about 2-1/2 miles along the main line of the Grand Trunk Railroad.

b. Gorham - Local high-water elevation is controlled by the dam. Since the valley here is a wide flat flood plain, it is suggested that the installation of flood gates in the dam will prove effective in reducing damages.

c. Rumford - High-water elevations in the city are controlled by the Middle dam and the channel conditions in the reaches downstream from it. Improvements have already been made by local interests as follows: A wall along the forebay of the upper dam to prevent overflow of the right bank at that point, lengthening of the upper bridge by adding another span, and a protective wall on the right bank below the Middle dam. The Oxford Paper Company has raised the fill on its property at the bend in the stream. Further improvement in flow conditions might be effected by ledge removal to improve flow conditions in the vicinity of the Morse and Memorial highway bridges. Improvement of the channel would result from removal of the approach fill to the abandoned railroad bridge on the left bank.

d. Jay - The stream at this point is divided by two small islands, and is obstructed by three dams and three short highway bridges which have been thrown up between the islands and the shores. The power house in the dam across the left channel takes up a considerable portion of the spillway capacity. Both the dams and the center bridge suffered damage during the March, 1936 flood. The following improvements are suggested: Set back the abutments and raise all three bridges: provide for flood gates in the dam across the left channel: clear away the ledge between the dam and bridge in the right channel. In reconstructing the bridges consideration should be given to their relocation at a safe distance upstream or downstream from the dams.

e. Livermore Falls and Chisholm - High-water elevations are controlled by the two dams in the towns. The major portion of the towns being situated well above the flood level, there is not much necessity for improvement. The highway bridge, when rebuilt, could be raised a few feet, and additional channel width obtained by setting back the right abutment.

f. Lewiston and Auburn - High-water elevations in these cities are controlled by the Union Water Power Company's dam and by natural channel conditions downstream. Appreciable encroachment on the stream has been caused by dumping along both river banks above and below South bridge. There is also some encroachment caused by filling in the left bank between the North bridge and the railway bridge. Possible channel improvements are the provision of flood gates in the Union Water Power Company's dam, removal of several encroachments in the channel, and excavation of the channel below the North bridge.

g. Lisbon Falls - High-water elevations here are controlled by the two dams in the town. Since the major portion of the town lies above the flood level, there appears no necessity for extensive channel improvement. The channel capacity may be increased by lowering the rock ledge in mid-channel, and removing the present pier on the small island near the left bank.

h. Brunswick - High-water elevations in the city are controlled by the two dams. There is considerable ledge rock above and below the lower dam, and the mill buildings forming part of the left forebay for the lower dam encroach upon the channel. The continuity of the upper dam is broken by two ledges which restrict the flow. The bridge, 1/4 mile upstream from the upper dam, is a double-decked structure, with the highway bridge underneath and the railway deck above. It is suggested that the following changes would improve flow conditions through the city: Provide flood gates in the lower dam: remove the ledges and islands above and below the lower dam: remove the highway (lower) deck from the bridge upstream, and rebuild it as a separate structure with adequate flood clearance. Consideration should also be given to the possibility of constructing a wall along the depressed left bank of the river above the lower highway bridge, to prevent overflow into the town of Topsham.

i. General - At many points along the river, shoals were formed during the March, 1936 floods, particularly at points where natural channel constrictions tend to form ice jams. For example, such ice jams formed during these floods just below two dams owned by the Pejepscot Mills (one 4-1/2 miles above Brunswick, the other the lower dam at Lisbon Falls) and not only increased the amount of damage to the company's property, but resulted in the deposition of material to form shoals which tend to increase possible future floods. The removal of these channel constrictions and shoals would improve flood conditions locally at numerous points along the river.

77. Diversion of Flood Flows. - Possibilities for the elimination of losses in the Androscoggin Basin by diverting floods waters into auxiliary channels are limited entirely to minor tributaries. The topography in the areas subject to flood damage preclude the practical consideration of this plan as a method of major control.

VI. FLOOD CONTROL AND OTHER WATER USES

78. Multiple-Purpose Reservoirs. - The possibility of obtaining additional storage capacity over and above that required for flood control at the four prospective flood-control reservoir sites, to provide for combined utilization of these reservoirs for flood control, conservation storage and power generation, was considered and estimates of the additional costs and additional benefits of such developments were made. The storage capacity allocated to flood control in the multiple-purpose reservoirs was equal to that selected in the studies for flood control alone and a separate additional capacity was added thereto for conservation storage. Preliminary estimates were used to establish the total cost of the combined reservoirs and the cost of the conservation portion was determined by deducting from this total the previously determined cost of providing flood-control storage alone in a smaller reservoir. The capacity of hydro-electric installation was based on the minimum regulated flow, minimum operating head and a 25% daily load factor during the low-flow periods.

79. Basic Assumptions. - The annual charges for the power development were estimated as follows:

	Hydro-Electric Installations	Dams and Reservoirs (Conservation Portion)
Interest on Investment	3.5%	3.5%
Amortization	2.5	0.5
Maintenance and Operation	2.0	1.0
Insurance	1.0	0.5
Total	9.0%	5.5%

Overall hydro-electric plant efficiency was assumed at 80% and the benefiting downstream plants were assumed to utilize 80% of the water released from the storage reservoirs. The power benefits resulting from operation of multiple-purpose reservoirs were evaluated on the following basis:

$12.50 per kilowatt of dependable capacity of installation at site
1.5 mills per kilowatt-hour of energy output
1.5 mills per kilowatt-hour of increase in energy output of existing plants below the reservoir

It was assumed that the value of dependable power is $12.50 per kilowatt per annum based on the annual fixed charges of steam power plants with estimated construction costs of $100 per kilowatt and fixed charges at 12.5%. The 1.5 mills per kilowatt-hour represents a conservative estimate of the fuel-saving value of the hydro-electric energy output. It is estimated that the actual fuel cost of steam-produced energy in the State of Maine is from 3 to 4 mills per kilowatt-hour. However, with steam produced energy comprising only 3% of the total in Maine, and with the great amount of hydro-electric power available, both existing and potential, it is believed that only a small portion of additional hydro-electric energy could be considered as replacing steam energy. Therefore the conservative value of 1.5 mills has been used for the economic analysis.

80. Rumford Reservoir as a Multiple-Purpose Development. - A preliminary examination of the multiple-purpose possibilities of the four sites considered for flood control definitely eliminated from further study the Dixfield, Buckfield and Oxford sites because of the relatively high cost of storage caused by excessive property damages encountered at elevations above those selected for flood control, the relatively small tributary drainage areas, and the low power heads available at these sites. A detailed study of the multiple-purpose possibilities was made, therefore, only for Rumford; a summary of the results is given in Table 33, following.

TABLE 33. RUMFORD RESERVOIR - MULTIPLE-PURPOSE DEVELOPMENT

Drainage Area	2,090 square miles	
Spillway Elevation	670 ft. above M.S.L.	
Flood-Control Storage Capacity	295,000 acre-feet	
Gross Conservation Storage Capacity	297,000 acre-feet	
Total Capacity of Multiple-Purpose Reservoir	592,000 acre-feet	
Net Conservation Storage Capacity (8-ft. draw-down)	100,000 acre-feet	
Prime Flow	2,050 c.f.s.	
Operating Head -		
(a) Maximum	45 feet	
(b) Minimum	37 feet	
(c) Average	43 feet	
Capacity of Hydro-Electric Installation	20,600 kw	
Average Annual Output	80,000,000 kwh	
Increase in Average Annual Output of the Downstream Plants	26,000,000 kwh*	
Benefits from Multiple-Purpose Development -		
Power Benefits		
(a) Dependable Capacity, 20,600 kw at $12.50	$275,000	
(b) Energy output at the site, 80,000,000 kwh at 1.5 mills	120,000	
(c) Incremental energy at existing down-stream plants, 26,000,000 kwh at 1.5 mills	39,000	
Total Annual Power Benefits		$ 434,000
Annual Flood-Control Benefits		322,700
Total Annual Benefits		$ 756,700
Estimated First Costs		
Combined Storage		$ 15,362,000
Carried by Flood Control	-$11,162,000	
Chargeable to Conservation	-$ 4,200,000	
Hydro-Electric Installation		1,814,000
Total Cost, Multiple-Purpose Development		$ 17,176,000
Annual Carrying Charges		
Conservation Storage	-$ 239,100	
Hydro-Electric Installation	169,000	
Flood Control	522,000	
Total Annual Charges, Multiple-Purpose Development		$ 930,100

* Based on a head of 407 feet, which is that portion of the present total head of 484 feet which has capacity to benefit from the increased low-water flow.

81. Results of Multiple-Purpose Reservoir Studies. - The ratio of estimated annual benefits to annual costs of a multiple-purpose development of the Rumford site, as determined from the foregoing tabulation, is found to be 0.81. The development of the site for such combined use does not appear, therefore, to be economically warranted under the existing conditions of development in the basin. In addition to the 484 feet of power head at present developed below the reservoir site, there are undeveloped potential power sites on the Androscoggin River aggregating some 71 feet. The benefits from the operation of conservation storage at Rumford Reservoir which would accrue to the existing plants and to the potential future plants, representing in all about 555 feet of head, amount to 35,000,000 kilowatt-hours. Assuming that the entire potential head below the reservoir were developed and the existing plants redeveloped so that all of them would have sufficient capacity to benefit from the increased low-water flow, the total value of power benefits would amount to $447,500 and the overall ratio of annual benefits to annual costs of the multiple-purpose development would increase only to 0.83. The foregoing ratios of benefits to costs of 0.81 and 0.83 were computed on the basis of value of energy at 1.5 mills per kilowatt-hour, as outlined in paragraph 79. This value may be regarded as conservative in areas where there is an actual demand for the replacement of steam energy by hydro-electric. Under existing conditions of power demand and legislative restrictions on the export of power, it is believed that no greater value can be placed upon the energy. Multiple-purpose reservoirs at the Dixfield, Buckfield and Oxford sites, which are not as favorably suited for such development as Rumford, would be even less justified economically.

82. <u>Possible Incidental Benefits of Flood-Control Reservoirs</u>. - The meteorological and hydrological studies in connection with flood-control reports for several New England rivers have indicated a definite seasonal character of the more severe damaging floods in the Androscoggin Basin, as well as in other New England basins. This seasonal character consists primarily of the preponderance of floods in the spring due to run-off from melting snow. Although flooding does result from extreme rainfall alone in other seasons of the year, there are few instances of serious damage from floods which have occurred in any but the spring season. In view of the seasonal character of the flood problem, the possibilities of utilizing a portion of flood-control reservoirs for conservation storage in the reduced-flood-threat season have been considered. The studies revealed that a lesser amount of flood-control storage is required to eliminate flood damages from the maximum flows which are possible from rainfall alone than is required in the limited season when the watershed is snow-covered and combined run-off from rainfall and melting snow is possible. It is believed that a plan of operation could be evolved through experience and study of watershed conditions which would permit the utilization of some portion of the flood-control storage reservoirs for conservation purposes after the winter's snow cover had melted and run off. In order to determine the value of such possible storage operation, a computation was made of the increased low-water flow which could be obtained. The results are shown in Table 34, following.

TABLE 34. EFFECT OF OPERATION OF FLOOD-CONTROL RESERVOIRS IN SEASONS OF REDUCED-FLOOD-THREAT ON MINIMUM MEAN MONTHLY FLOW AT AUBURN, ME.

(All flows in cubic feet per second)

	Four-Reservoir Combination (R-D-B-O)	Three-Reservoir Combination (R-D-B)	Rumford Reservoir Alone
Present minimum flow*	1,900	1,900	1,900
Minimum flow with indicated reservoirs	2,780	2,650	2,530
Increase	880	750	630

The possible increased low-water flow represents a potential benefit to downstream power installations, water supplies, sanitation and recreation. At the present time the water supply and recreational needs of the basin are such that little benefit could be realized. Pollution of the river is a serious problem at the present time and the need for sanitation measures has been recognized by local and other agencies concerned for a number of years. Because of the difficulties of obtaining cooperation of beneficiaries of any improvement in sanitary conditions, and also because of the incidental and therefore problematical status of obtaining improved sanitary conditions by means of an increased low-water flow from flood-control reservoirs, it is not considered advisable to place a value on the potential benefits of such an increase in low-water flow at the present time. As a measure of value of the operation of flood-control reservoirs for conservation storage in a reduced-flood-threat season, the possible benefits to existing downstream power installations have been determined as shown in the following table.

* Based on the dry years of 1929-30.

TABLE 35. INCIDENTAL POWER BENEFITS RESULTING FROM OPERATION OF FLOOD-CONTROL RESERVOIRS IN SEASONS OF REDUCED-FLOOD-THREAT

Reservoirs	Increased Energy Output Kilowatt-hours	Value at 1.5 Mills Per Kilowatt-hour
Combination of Rumford, Dixfield, Buckfield and Oxford Reservoirs	48,000,000	$ 72,000
Combination of Rumford, Dixfield and Buckfield Reservoirs	46,000,000	$ 69,000
Rumford Reservoir alone	39,000,000	$ 58,000

The foregoing possible additional power benefits are based on the following aggregate heads below the reservoirs: Rumford, 407 feet; Dixfield, 261 feet; Buckfield, 172 feet, and Oxford, 64 feet. These represent the operating heads developed below the respective reservoirs at installations of sufficient capacity to benefit from the increased flow. The total developed heads below each reservoir are: Rumford, 484 feet; Dixfield, 308 feet, Buckfield, 233 feet, and Oxford, 227 feet. Even if the utilization of flood-control storage in the reduced-flood-threat season were found to be feasible and the foregoing benefits could be realized, the ratio of benefits to costs for the four-, three- and one-reservoir combinations at the present time would be increased only to 0.53, 0.64 and 0.73 respectively. If the number and capacity of downstream power installations increase in the future and improvement of water supply, sanitation and recreational conditions becomes more desirable, the value of an increased low-water flow would be greatly enhanced and, it is believed, would be worthy of consideration at that time.

VII. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

83. Summary of Possibilities for Reservoir Control. - Sufficient control of floods in the Androscoggin Basin to eliminate 82.5% of the average annual flood damages could be provided with a system of four reservoirs, Rumford, Dixfield, Buckfield and Oxford. A combination of the first three named reservoirs would eliminate about 79% of the damage and Rumford Reservoir alone would eliminate 71%. Of the total drainage area of 3,470 square miles, the 1,095 square miles (31.6% of the total basin) above Errol Dam are already well regulated by existing power storage. Including this area, the resulting percentage of the total basin area controlled by the four-, three-, and one-reservoir combinations described above would be 74.1, 67.5 and 59.4, respectively. None of these combinations of reservoir control are economically justified at the present time, however. Rumford Reservoir alone, the most favorable prospective development, has a ratio of flood-control benefits to costs of only 0.62. If it were found feasible to utilize the reservoirs for conservation storage in the reduced-flood-threat season, additional benefits to downstream power installations, sanitation, water supply and recreation would result. At the present time, however, these additional benefits would not be sufficient to justify construction of the projects. In addition, there are practicable possibilities for multiple-purpose developments for flood control, conservation storage and power development. Similarly, however, the prospective benefits of the most favorable project for multiple purposes, Rumford Reservoir, would not be economically justified at the present time, having a benefits-costs ratio of only 0.81.

84. Local Flood Protection. - The most favorable opportunities for flood protection in local areas are at Auburn-Lewiston and Rumford-Mexico. There are several sections in these communities which could

be protected by means of levees or river walls, but the benefits to be gained at the present time would be less than the costs. There appear to be no economically favorable opportunities for local flood protection by this or other means. The flood problem in several communities could be alleviated by reconstruction or removal of dams, bridges and buildings which affect flood flows. These corrective measures could be accomplished economically only when the structures have reached the end of their economic or physical life.

85. Zoning Regulations. - Although there are no economically justified possibilities for channel improvements either throughout the basin generally or in specific local areas, it is believed that much improvement of channel conditions, with resulting flood control benefits, could be obtained by regulations designed to eliminate existing channel encroachments, inadequate channel clearances and developments in areas subject to frequent flooding and to prevent the growth of such conditions in the future. Such regulation could be obtained by municipal and state zoning laws.

86. Flood Warnings. - Some measure of flood control may also be realized by correlating the predictions of storm rainfall and studies of saturation, snow cover and other watershed conditions, thus making possible the draw-down of existing storage before the predicted storms. The extent and water equivalent of the snow cover and underlying ground conditions are very important flood factors in this basin and additional data to those now being collected by the Weather Bureau and other agencies should be very useful in the future. Extension and correlation of investigations of hydrologic conditions in the basin through cooperation of all agencies concerned are desirable, therefore, to the end that improved flood forecasts and adequate warning may be given to the public and to the agencies controlling existing and prospective storage. The practice of these

methods is already being carried on by private storage operators in the Androscoggin Basin, with considerable success in controlling flood flows. The operators have arranged for cooperation with local Weather Bureau officials and agencies collecting hydrological data to the full extent of present facilities for exchange of information. They have expressed the opinion that an aerial photographic survey of the river and its principal tributaries would be very useful for better execution of a flood-warning system and control of existing storage. Such a survey should properly come under the jurisdiction of the U. S. Weather Bureau, the agency charged with responsibility for flood forecasts and would appear desirable if compatible with the plans of that agency.

87. Conclusions. - Improvement of the Androscoggin River, Me.& N.H., for flood control by means of new construction does not appear to be economically justified at the present time. It is possible, however, that the need and justification for flood-control works may increase if the value of developments within the valley increases. In addition, it may be possible, at some future date, to provide flood control by means of multiple-purpose reservoirs. Such development is not warranted at the present time but may become justified if there should be an increased demand for hydro-electric power in the State of Maine. Future developments as to the value of flood-control storage in providing incidental benefits to power developments, water supply, sanitation and recreation may also increase the justification of flood-control reservoirs. Flood protection of local damage centers by means of levees or river walls and channel improvement is not warranted. These methods may become justified for some localities in the future if the value of property in concentrated areas subject to flooding should increase. It is believed, however, that local flood problems in many cases could be alleviated by reconstruction or removal, at the end of

their economic or physical life, of dams, bridges and buildings which affect flood flows and by the provision of zoning regulations to eliminate channel encroachments and development in areas subject to frequent flooding. Regulations might also be provided to limit development in the areas best suited for reservoirs in order to insure their availability at a reasonable cost if the need for reservoir control should increase. An appreciable measure of flood control is already provided by the operation of existing storage in the basin. Continuation of present practices and assistance to the storage operators in enhancing the value of the practice by means of improved flood-forecasting services are desirable.

88. <u>Recommendations</u>. - It is recommended that no improvement of the Androscoggin River for flood control by means of new construction be undertaken at the present time, but that the Department cooperate with any State or Federal agencies concerned in improvement of the flood situation by coordination of existing storage, flood-warning and forecasting services, and zoning regulations.

A. K. B. Lyman
Colonel, Corps of Engineers
District Engineer

Inclosures:
Figures 1 to 40

LIST OF DRAWINGS ACCOMPANYING THIS REPORT

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY

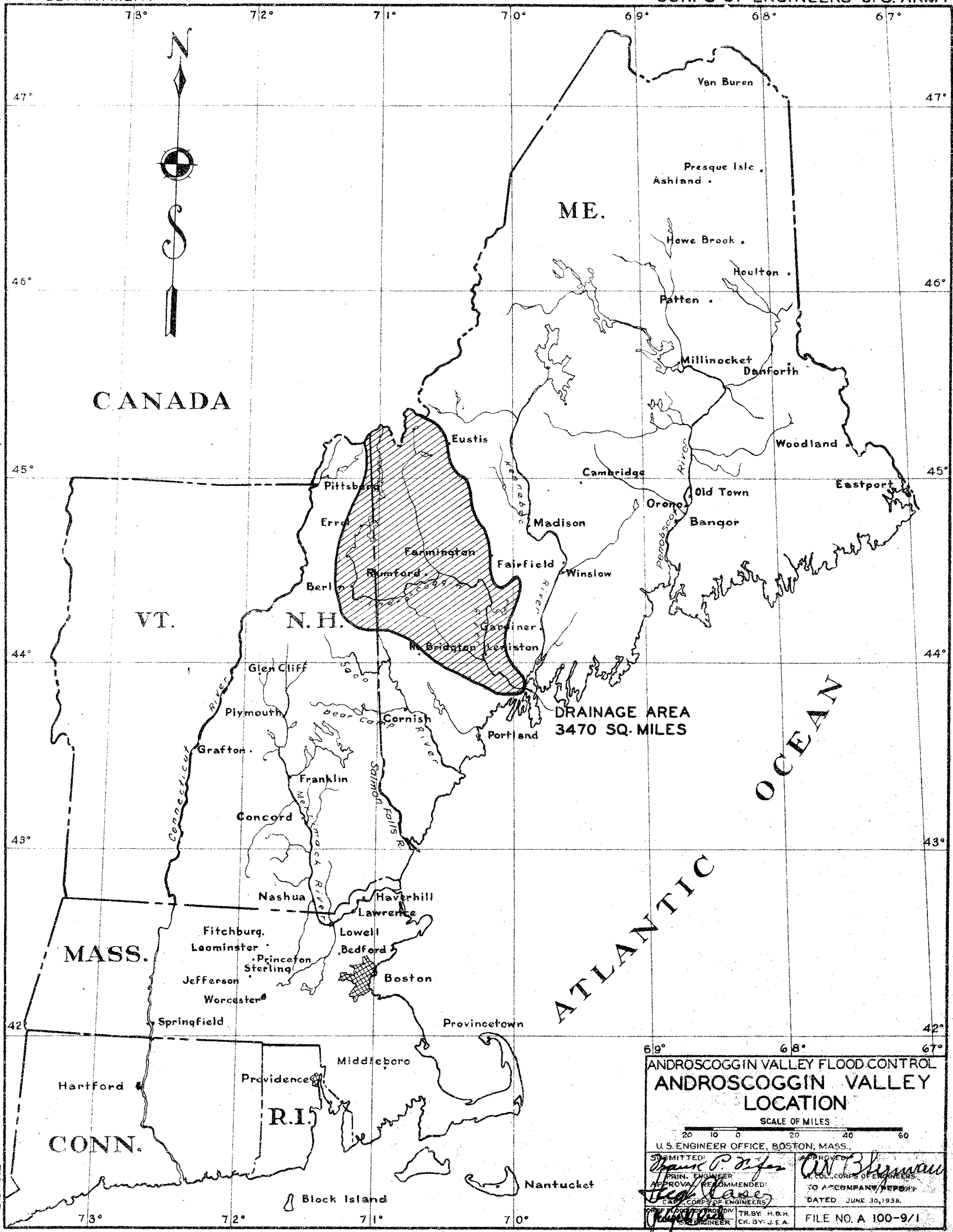
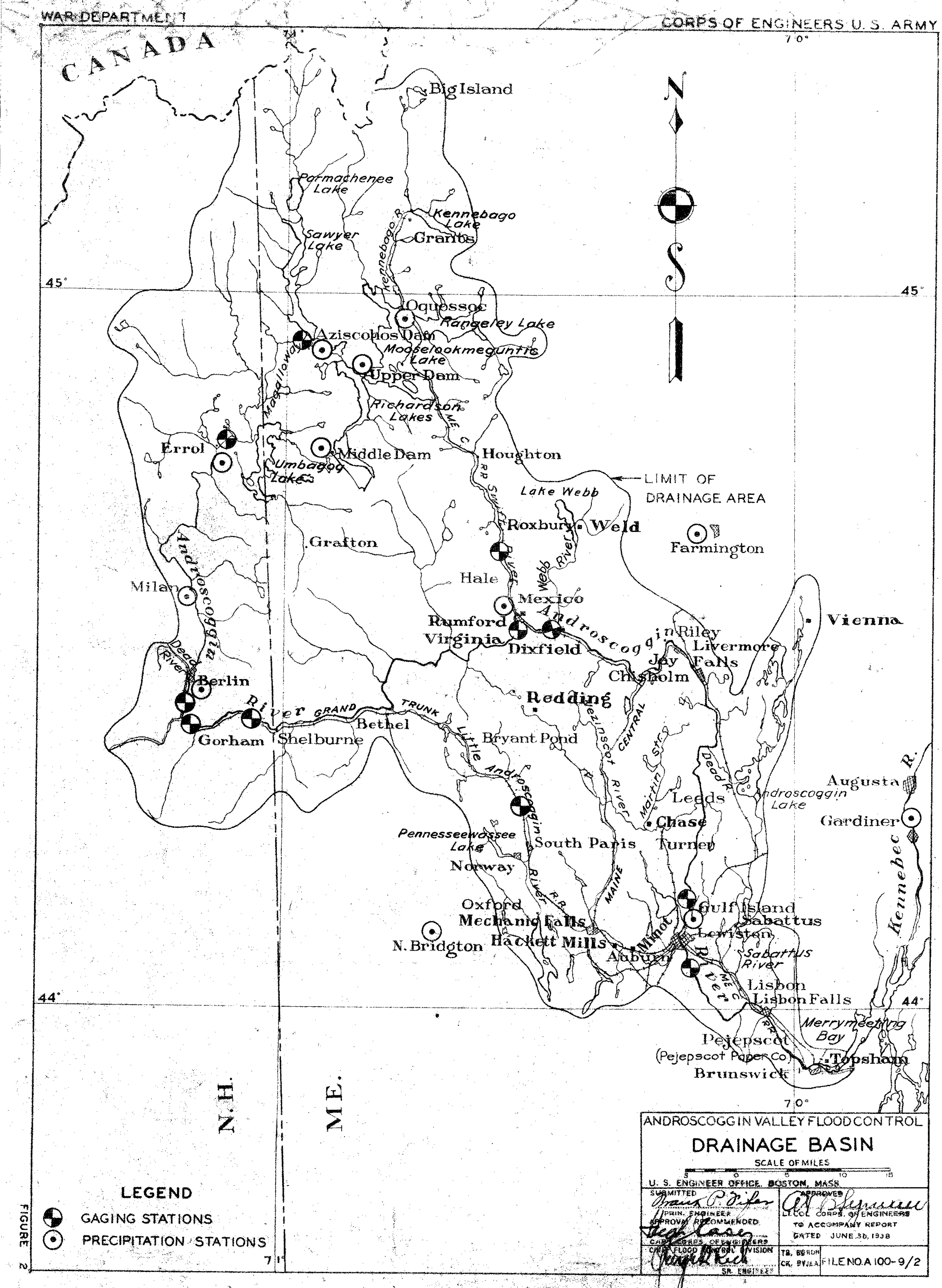


FIGURE 1


WAR DEPARTMENT
CORPS OF ENGINEERS U. S. ARMY
CANADA
N
S
Big Island
Parmachenee Lake
Kennebago Lake
Sawyer Lake
Grants
Kennebago R.
45°
Oquossoc
Rangeley Lake
Aziscohos Dam
Mooselookmeguntic Lake
Upper Dam
Magalloway
Richardson Lakes
Errol
Middle Dam
Umbagog Lake
Houghton
LIMIT OF DRAINAGE AREA
Lake Webb
Roxbury
Weld
Farmington
Grafton
Androscoggin
Hale
Webb River
Swift River
Milan
Mexico
Rumford
Virginia
Dixfield
Androscoggin
Riley
Vienna
Livermore Falls
Jay
Chisholm
Dead River
Berlin
Redding
River
GRAND TRUNK
Bethel
Gorham
Shelburne
Bryant Pond
Little Androscoggin
Nezinscot River
CENTRAL
Martin Str.
Dead R.
Augusta
Androscoggin Lake
Leeds
Chase
Gardiner
Pennesseewassee Lake
South Paris
Turner
Norway
MAINE
Kennebec R.
Oxford
Mechanic Falls
Gulf Island
Sabattus
N. Bridgton
Hackett Mills
Minot
Lewiston
Auburn
Sabattus River
River
Lisbon
Lisbon Falls
44°
Merrymeeting Bay
Pejepscot
(Pejepscot Paper Co.)
Topsham
Brunswick
70°
71°
N.H.
ME.
LEGEND
GAGING STATIONS
PRECIPITATION STATIONS
ANDROSCOGGIN VALLEY FLOOD CONTROL
DRAINAGE BASIN
SCALE OF MILES
5 0 5 10 15
U. S. ENGINEER OFFICE, BOSTON, MASS.
SUBMITTED
PRIN. ENGINEER
APPROVAL RECOMMENDED
CAPT. CORPS OF ENGINEERS
CHIEF FLOOD CONTROL DIVISION
SR. ENGINEER
APPROVED
LT. COL. CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED JUNE 30, 1938
FILE NO. A 100-9/2
FIGURE 2

WAR DEPARTMENT CORPS OF ENGINEERS U.S. ARMY

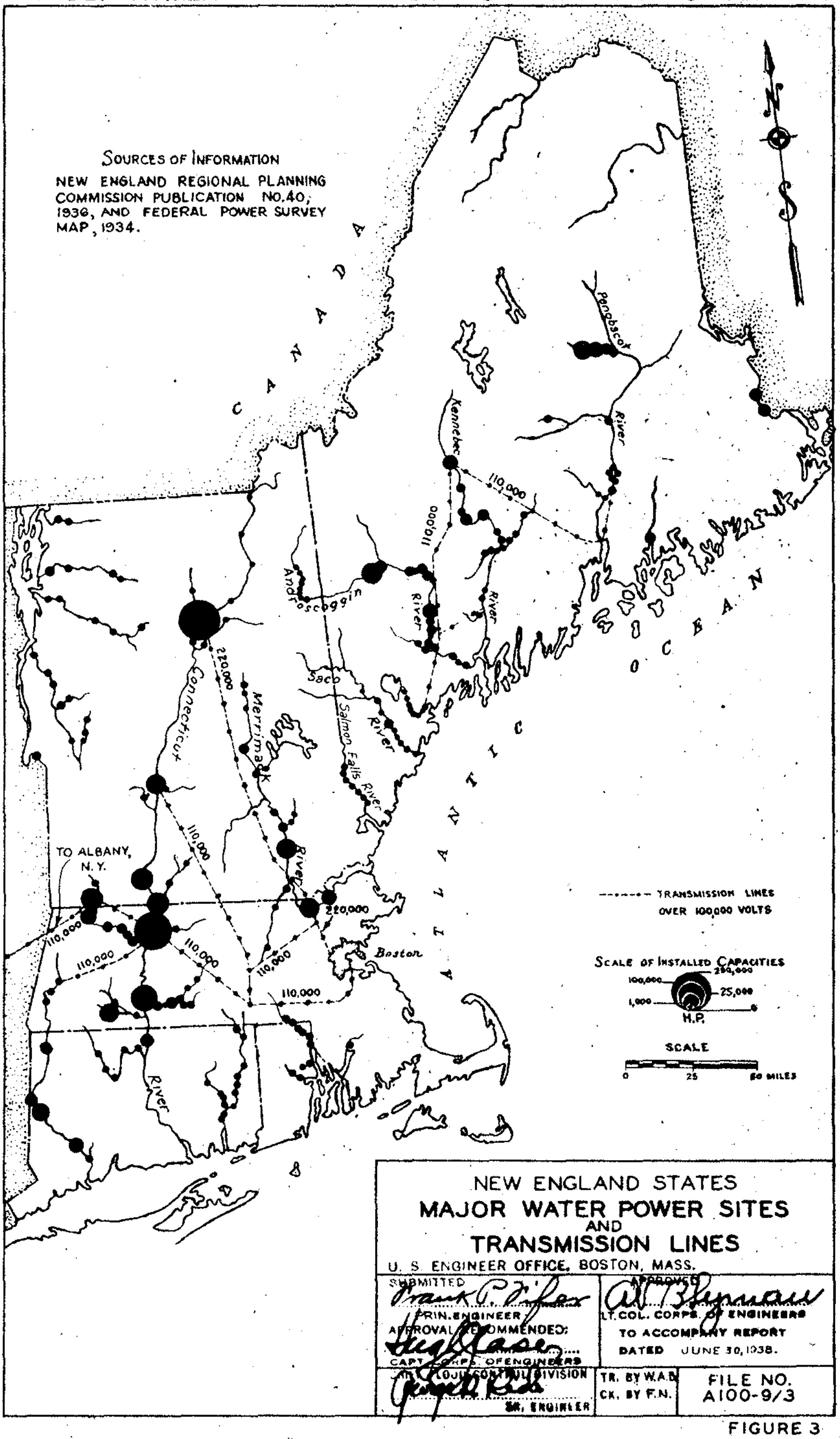
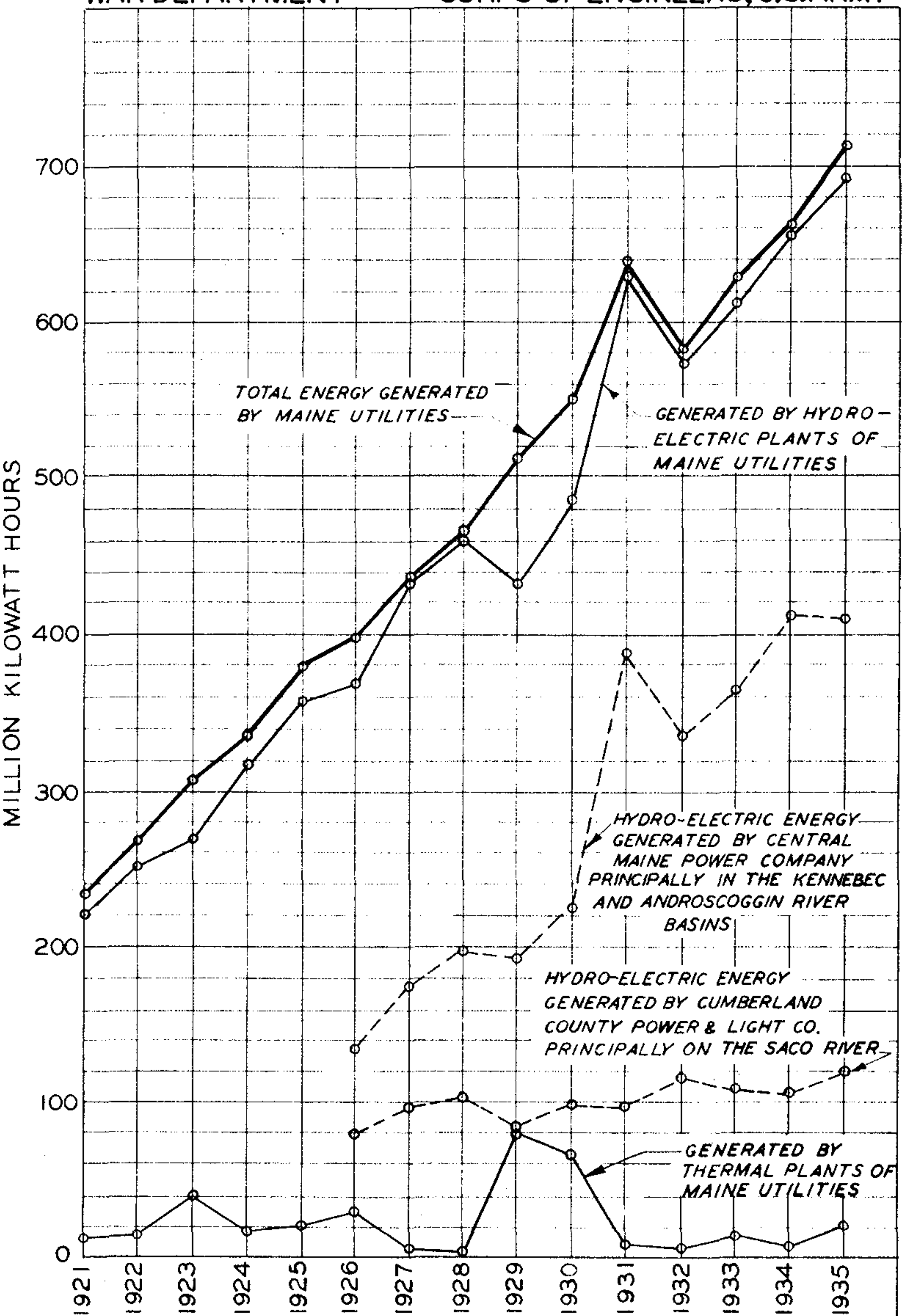


FIGURE 3

WAR DEPARTMENT CORPS OF ENGINEERS, U.S. ARMY



Source of information: Biennial Reports of Public Utilities Commission, State of Maine.

ANDROSCOGGIN VALLEY FLOOD CONTROL
PRODUCTION OF ELECTRICAL ENERGY BY PUBLIC UTILITIES
STATE OF MAINE

U.S. ENGINEER OFFICE, BOSTON, MASS.

APPROVAL RECOMMENDED *James W. Bratton* CAPT. CORPS OF ENGINEERS	APPROVED *A. T. Blennase* LT. COL. CORPS OF ENGINEERS DISTRICT ENGINEER
SUBMITTED *John E. Allen* SENIOR ENGINEER	TO ACCOMPANY REPORT DATED JUNE 30, 1938.
PREPARED BY: *Algie Groden* ASSOCIATE ENGINEER	TR. BY M.G. CK. BY V.K. — FILE NO A100-9/4

FIGURE 4

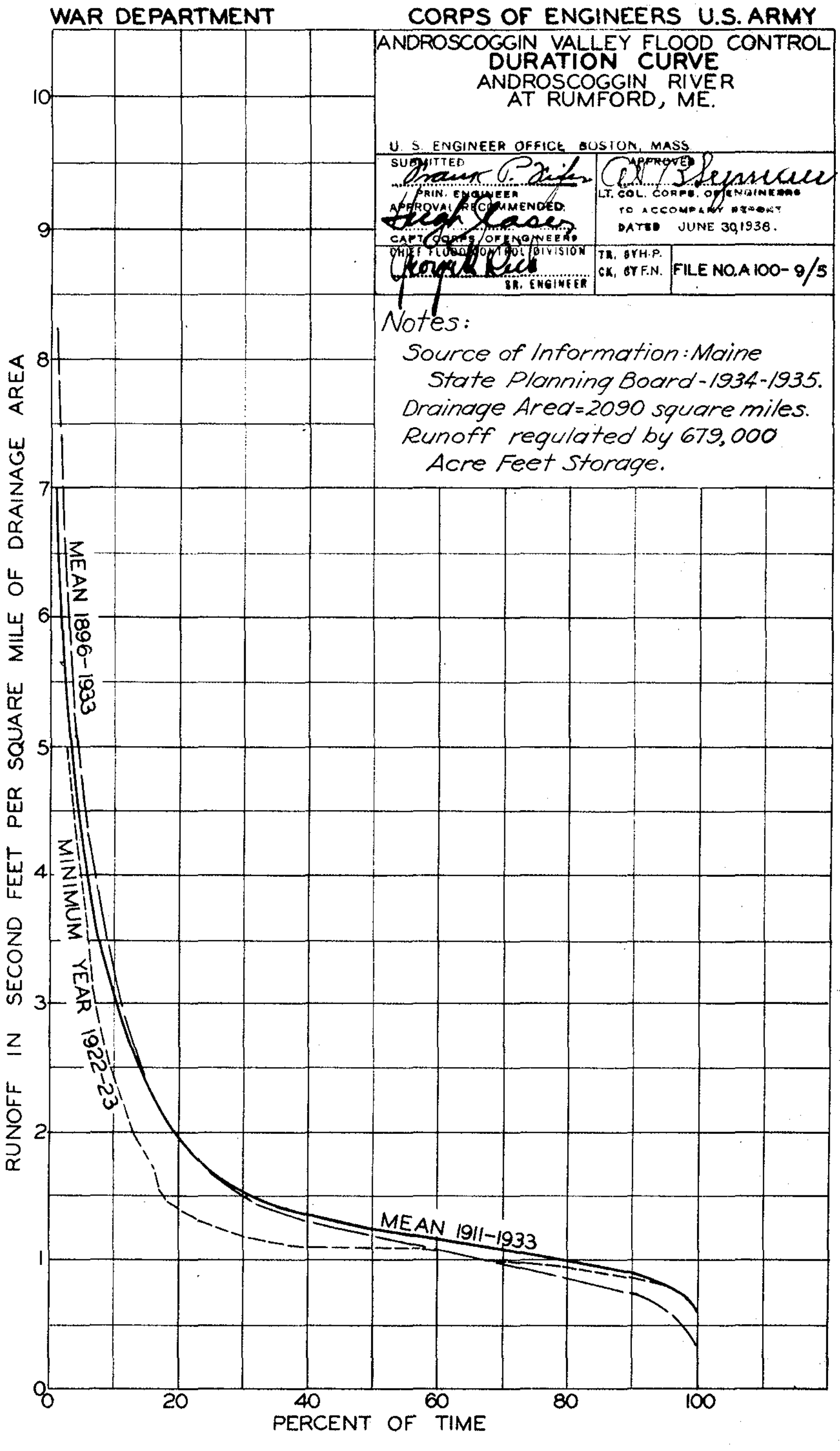

WAR DEPARTMENT
CORPS OF ENGINEERS U.S. ARMY
ANDROSCOGGIN VALLEY FLOOD CONTROL
DURATION CURVE
ANDROSCOGGIN RIVER
AT RUMFORD, ME.
U. S. ENGINEER OFFICE, BOSTON, MASS.
SUBMITTED
PRIN. ENGINEER
APPROVAL RECOMMENDED
CAPT. CORPS OF ENGINEERS
CHIEF FLOOD CONTROL DIVISION
SR. ENGINEER
APPROVED
LT. COL. CORPS OF ENGINEERS
TO ACCOMPANY REPORT
DATED JUNE 30, 1938.
TR. BY H.P.
CK. BY F.N.
FILE NO. A 100- 9/5
Notes:
Source of Information: Maine State Planning Board - 1934-1935.
Drainage Area = 2090 square miles.
Runoff regulated by 679,000 Acre Feet Storage.
MEAN 1896-1933
MINIMUM YEAR 1922-23
MEAN 1911-1933
RUNOFF IN SECOND FEET PER SQUARE MILE OF DRAINAGE AREA
PERCENT OF TIME
0
1
2
3
4
5
6
7
8
9
10
20
40
60
80
100

FIGURE 5

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY

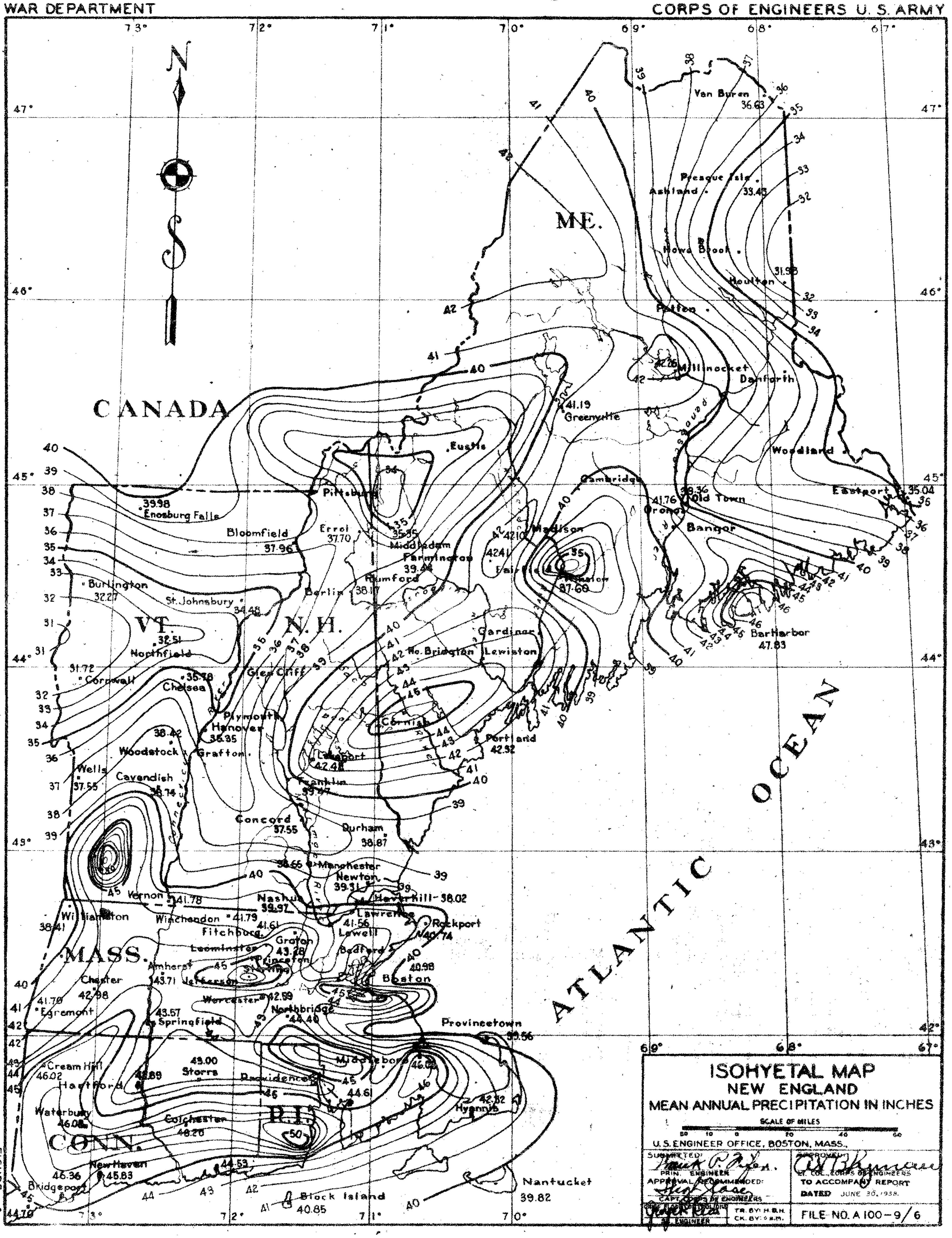


FIGURE 6

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY

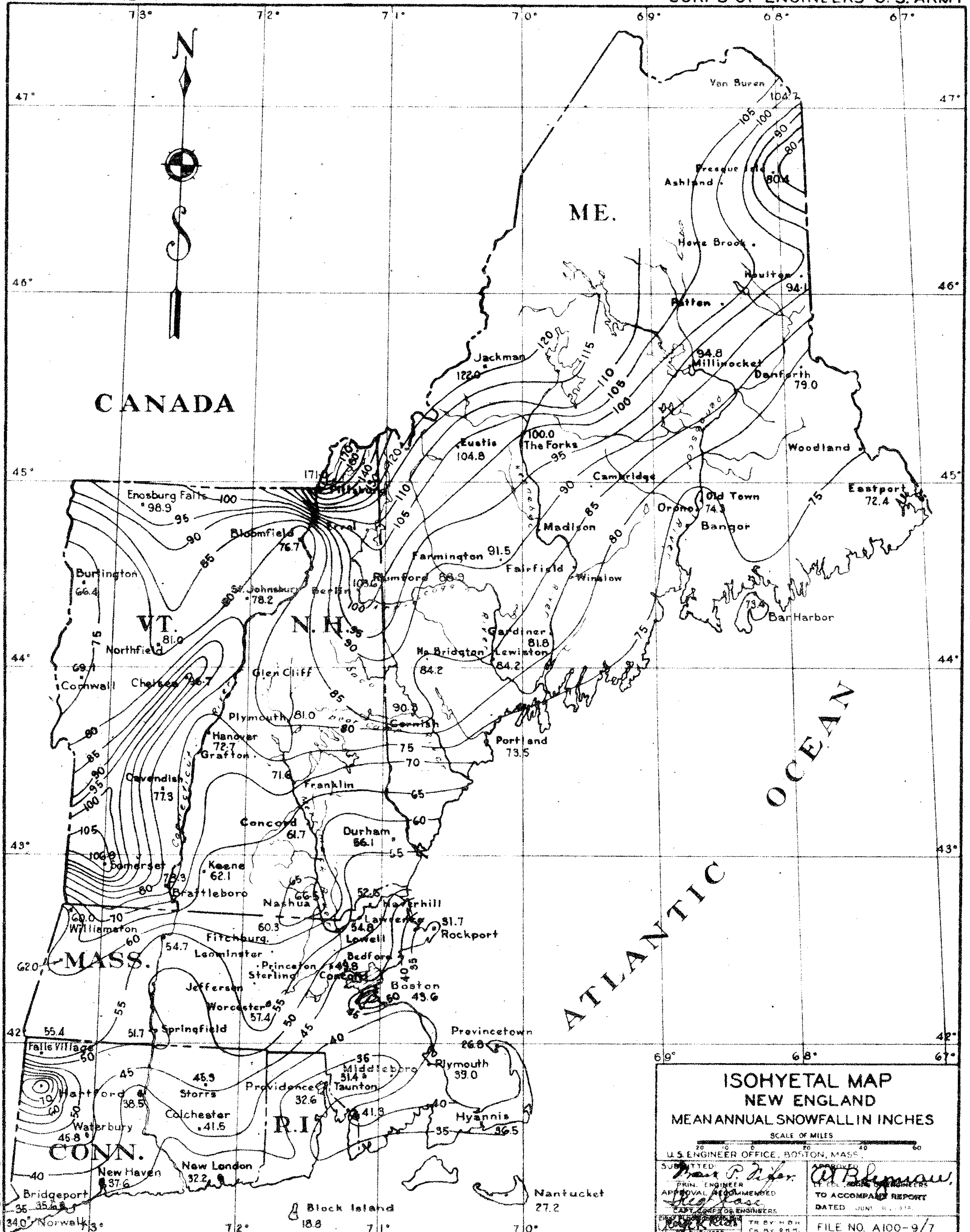


FIGURE 7

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY

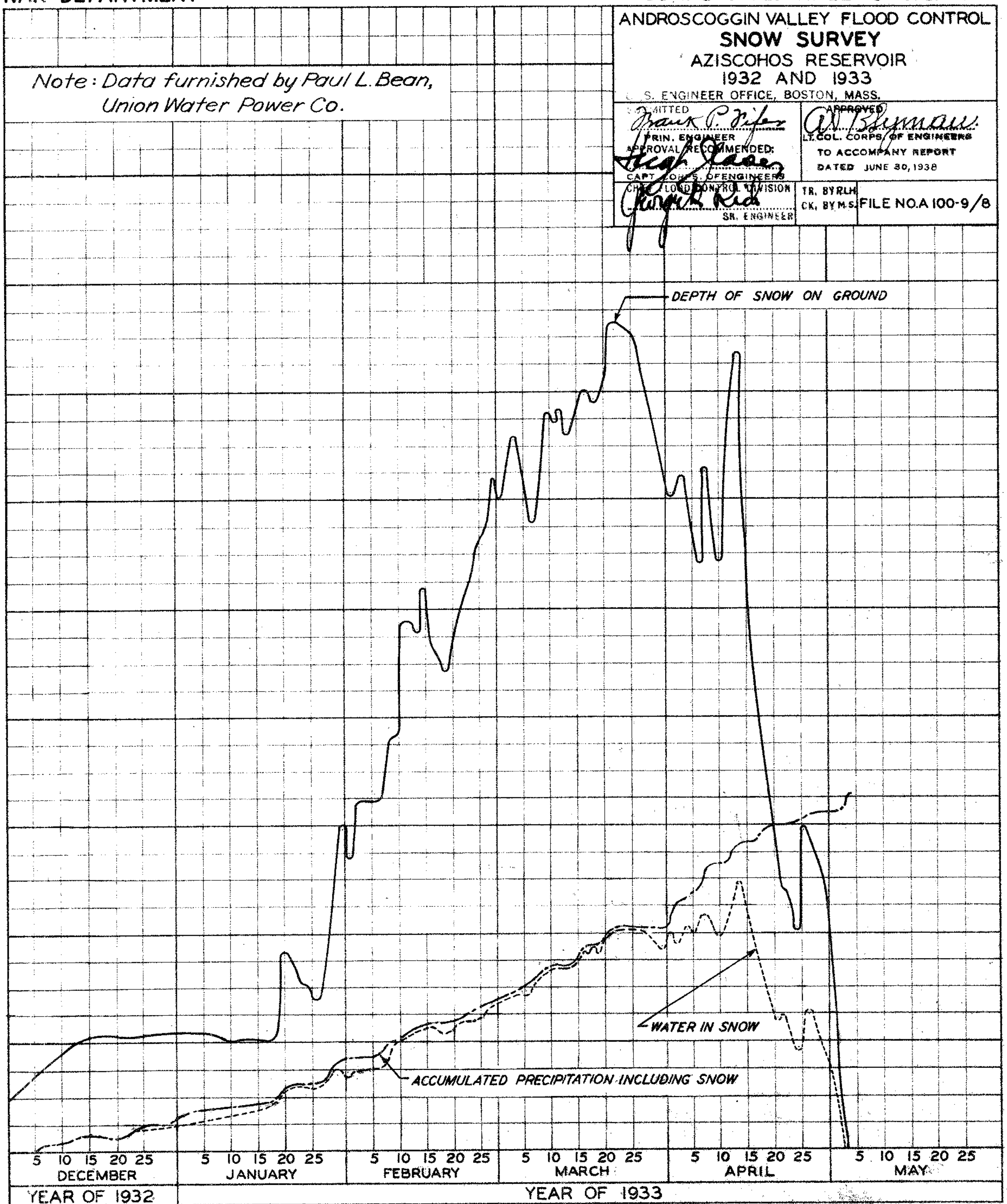


FIGURE 8

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY

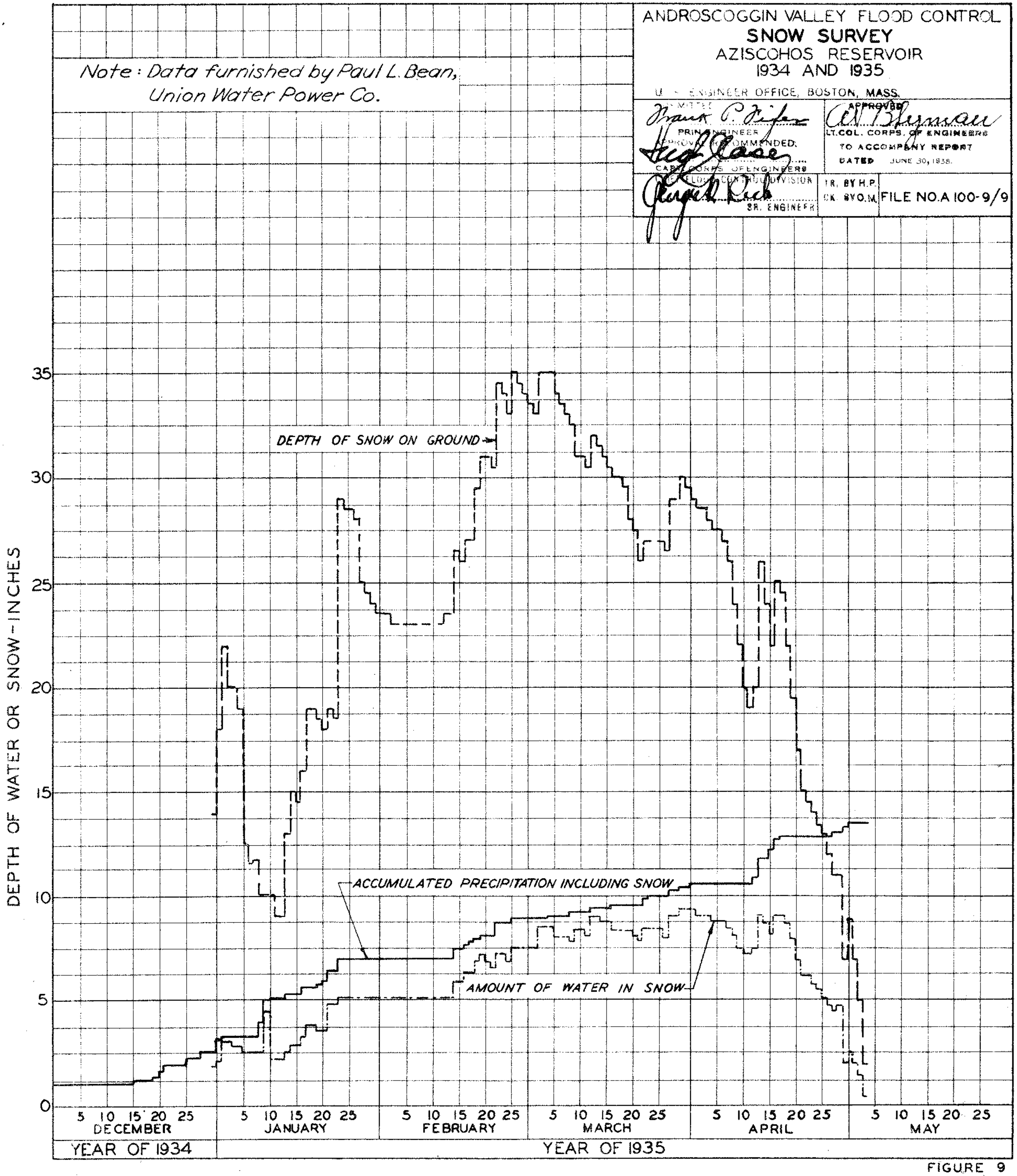


FIGURE 9

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY

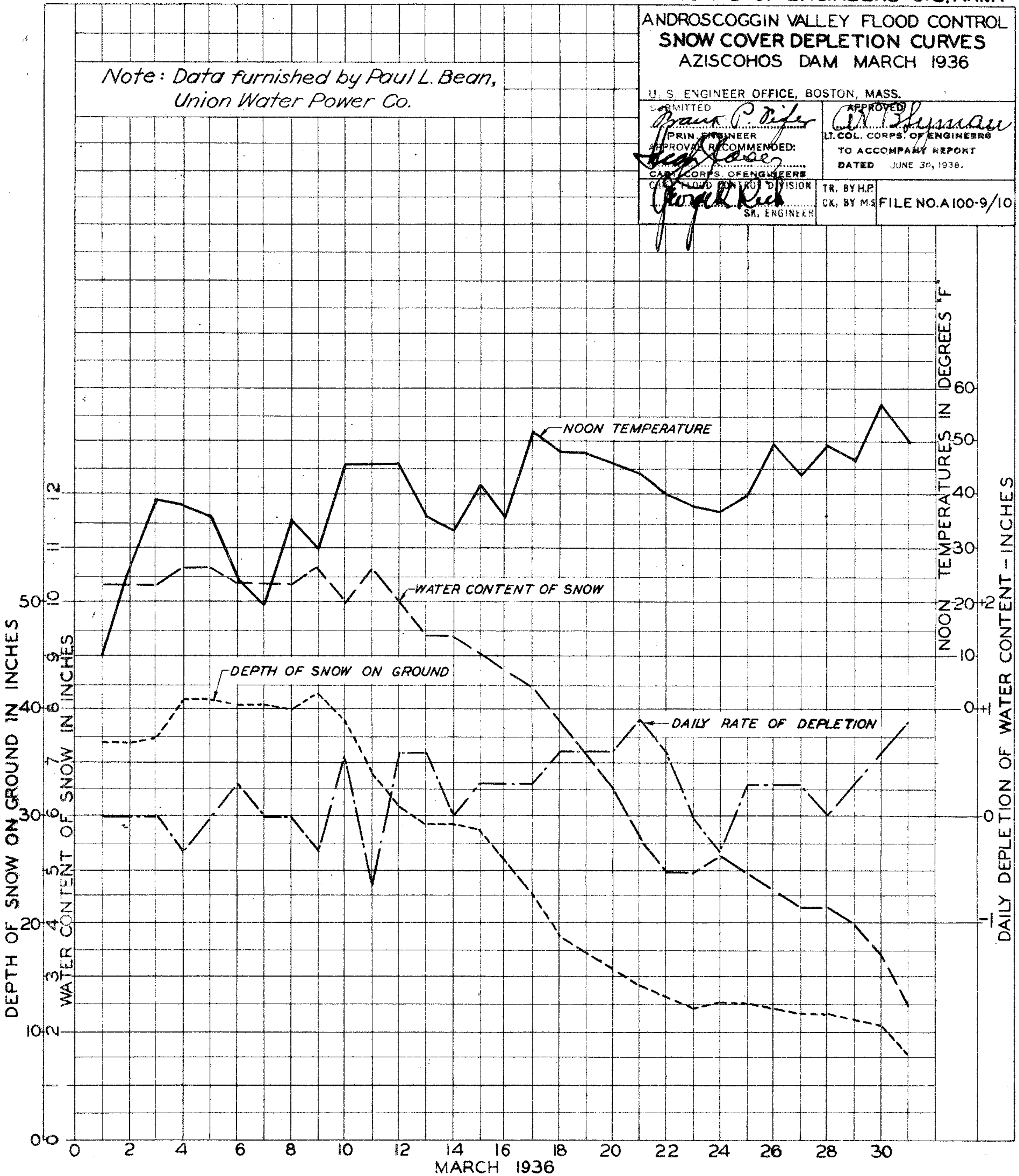


FIGURE 10

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY

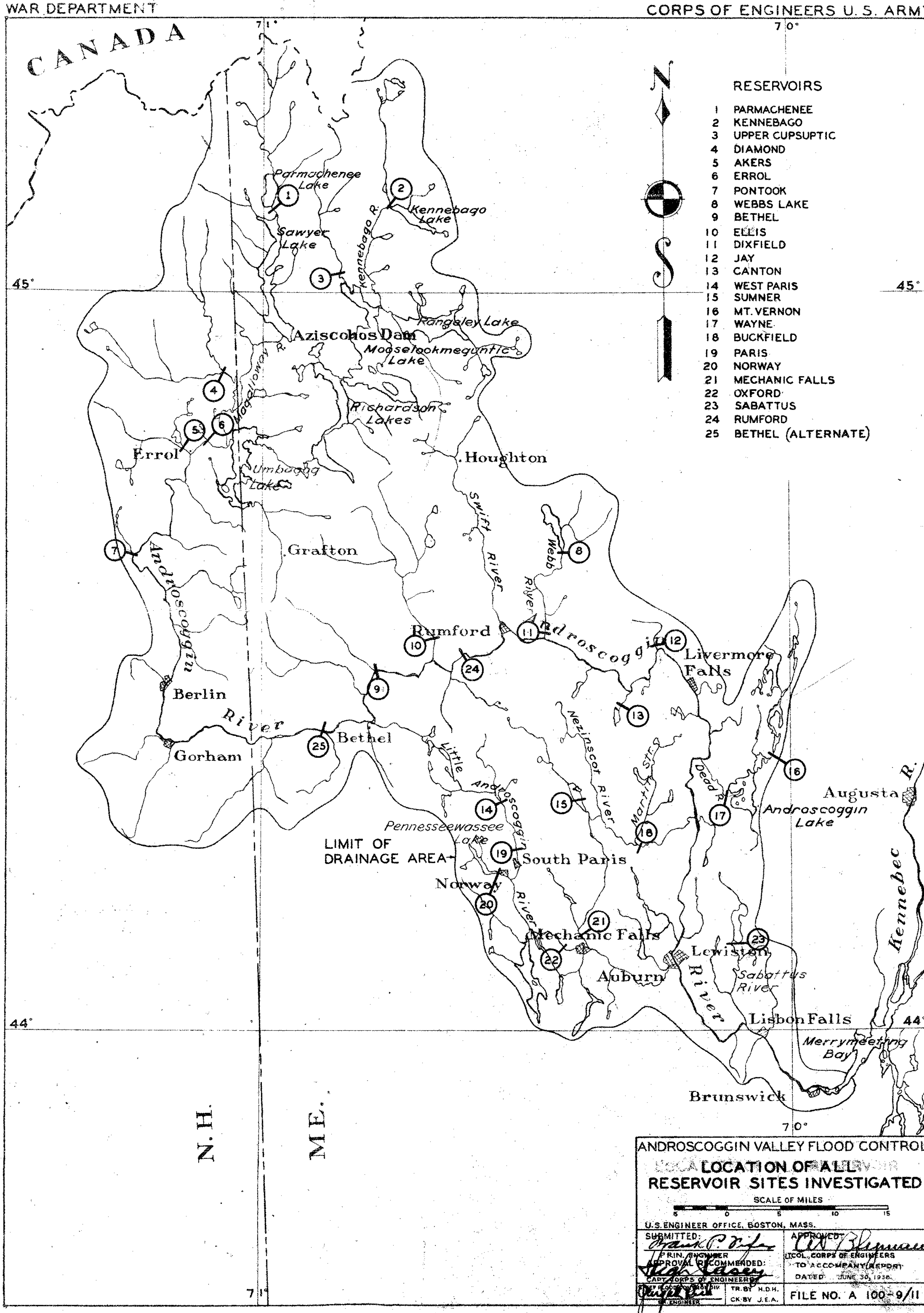
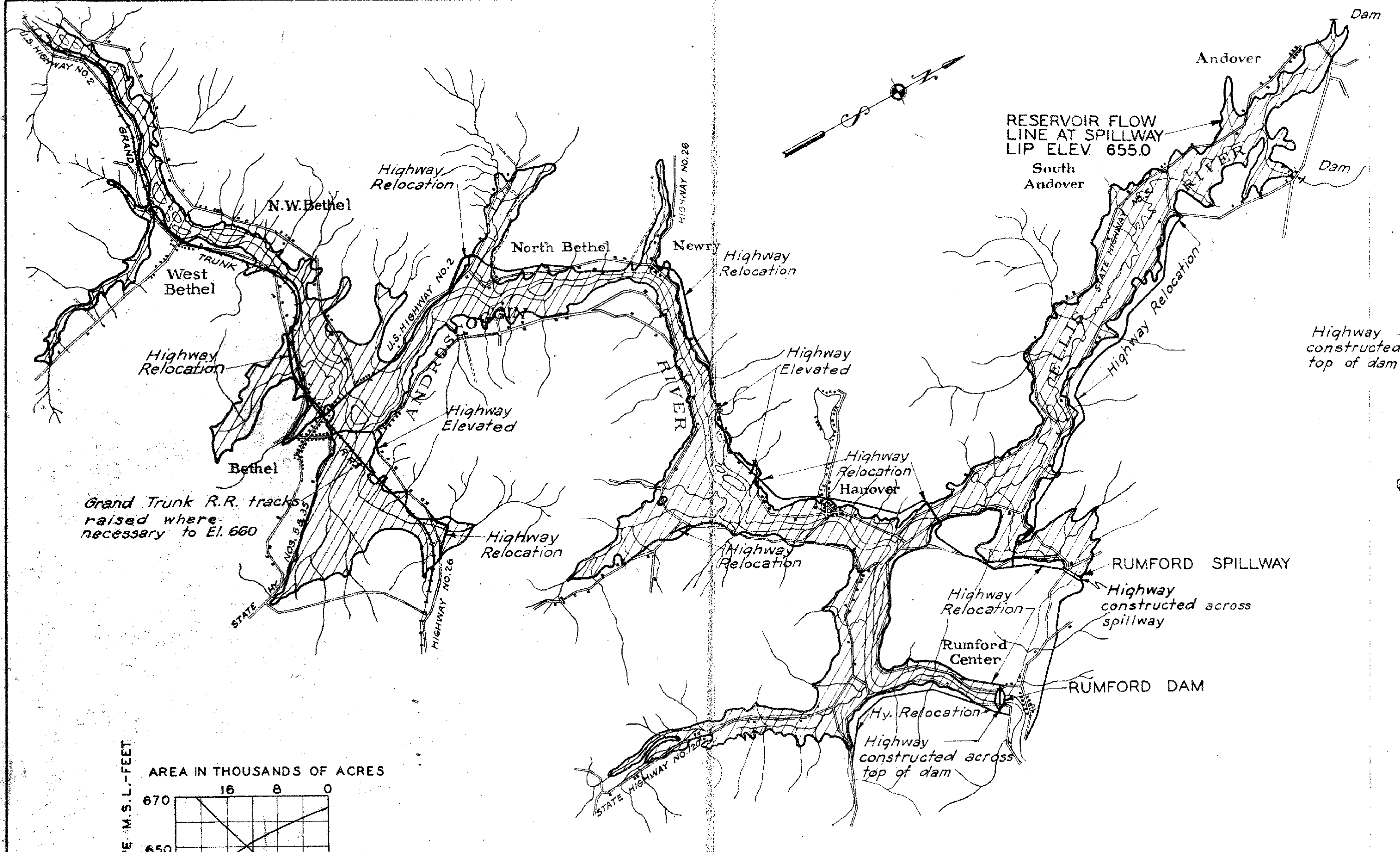
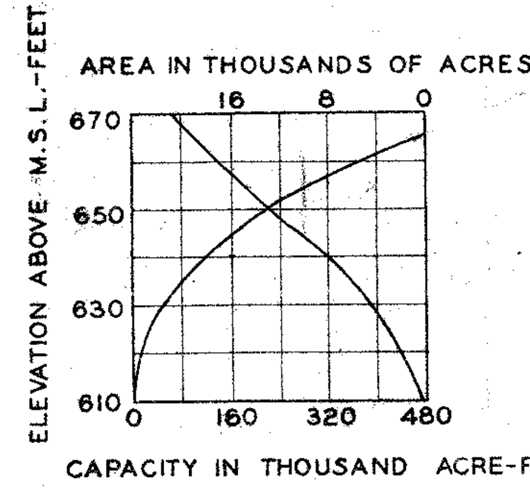


FIGURE 11



RESERVOIR

SCALE IN FEET: 8000 0 8000 16000

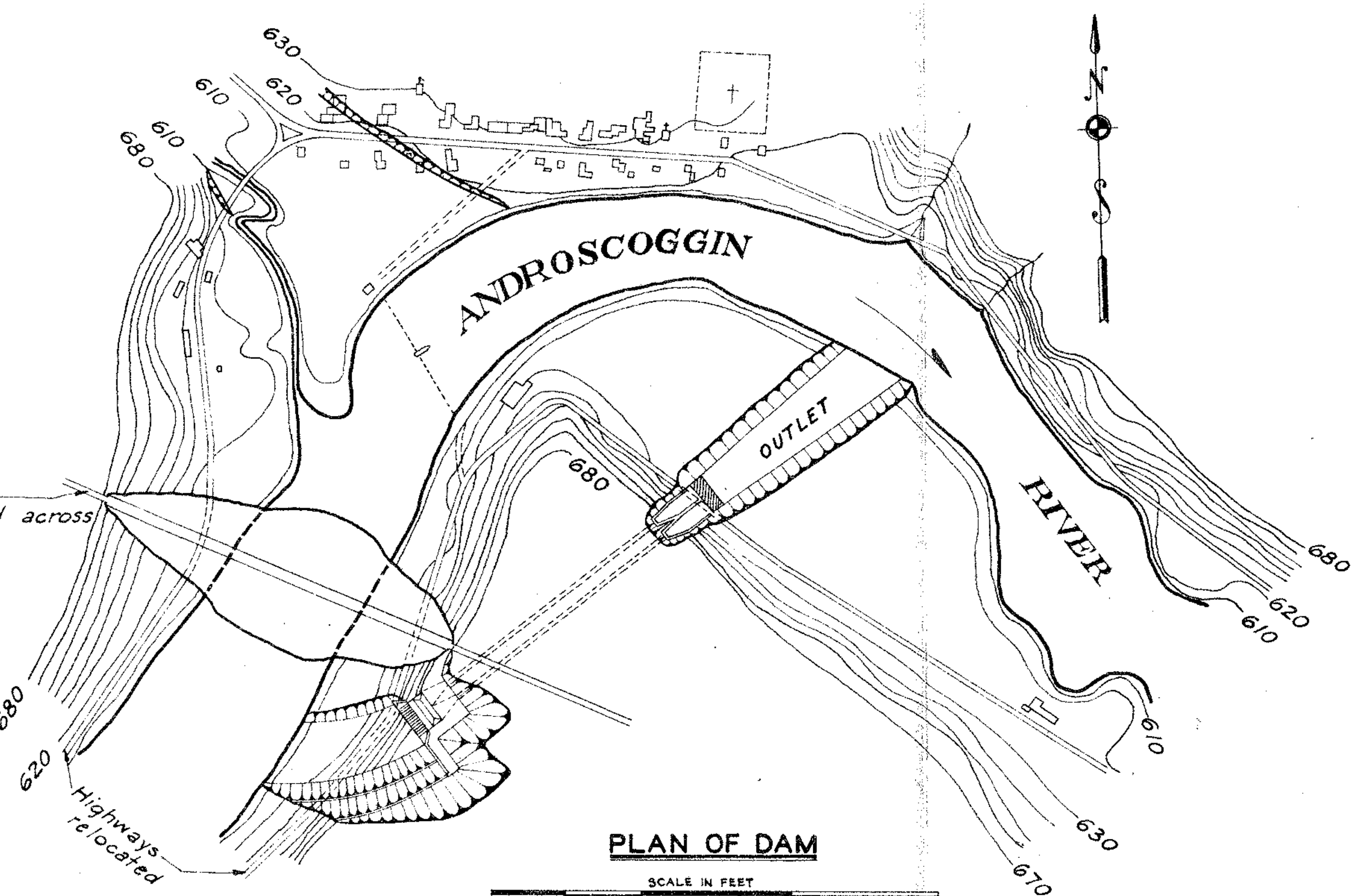


AREA AND CAPACITY CURVES

Note: Capacity of reservoir to spillway lip at El. 655 is equal to 5.7 inches of runoff over *365 (net) square miles of area of tributary drainage basin.

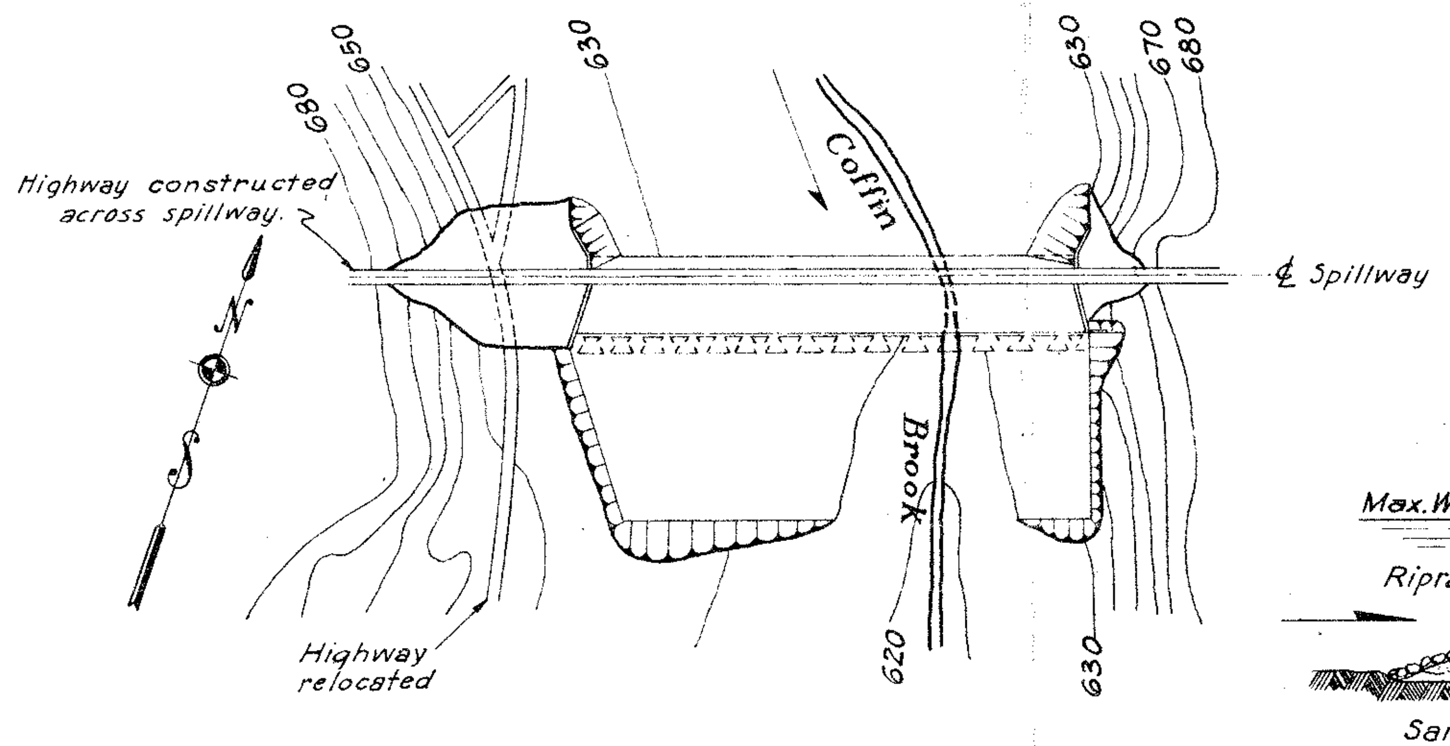
* Total drainage area is 2060 sq. mi. of which 1095 sq. mi. are controlled by the operation of reservoirs owned by Union Water Power Co., storage being regularly drawn down in anticipation of flood runoff.

Note: In view of high ratio of project fixed charges to benefits as well as shortage of funds and time, foundation area was not drilled. Foundation conditions shown on this drawing are based on geologists field reconnaissance.



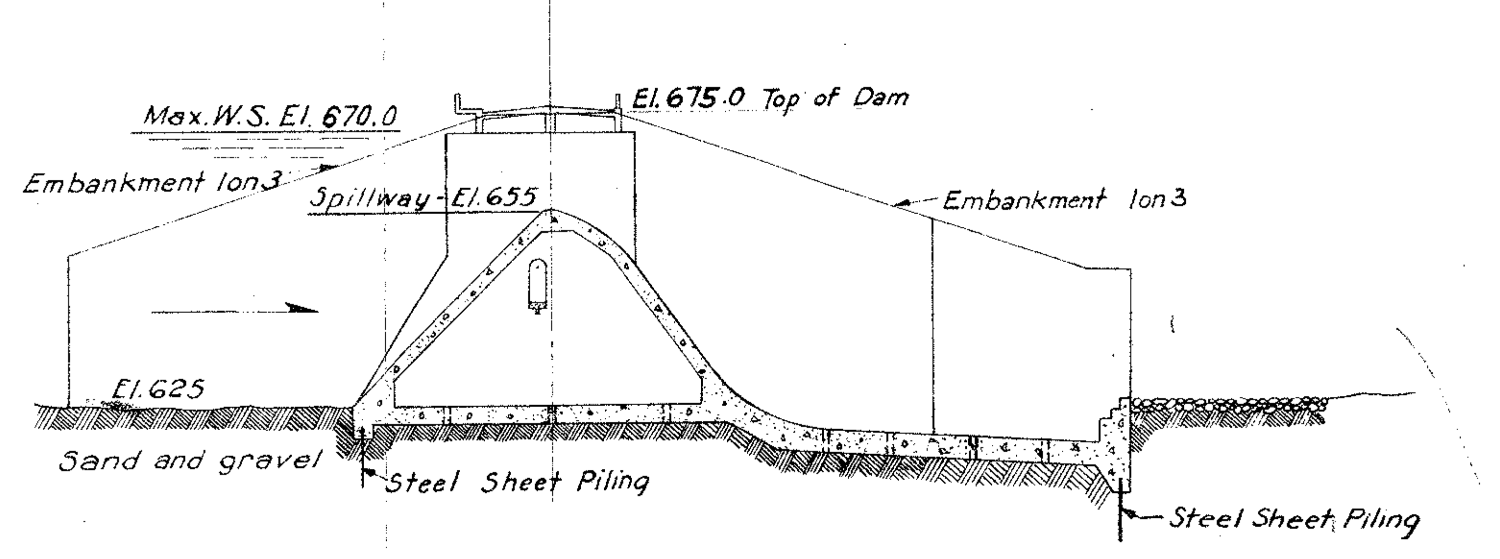
PLAN OF DAM

SCALE IN FEET: 600 0 600 1200



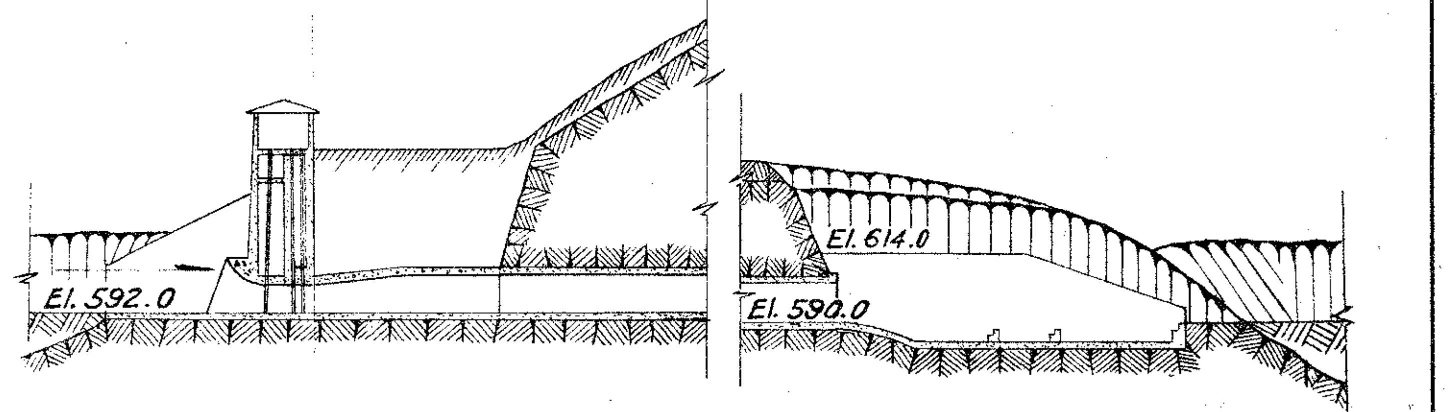
PLAN OF SPILLWAY

SCALE IN FEET: 300 0 300 600



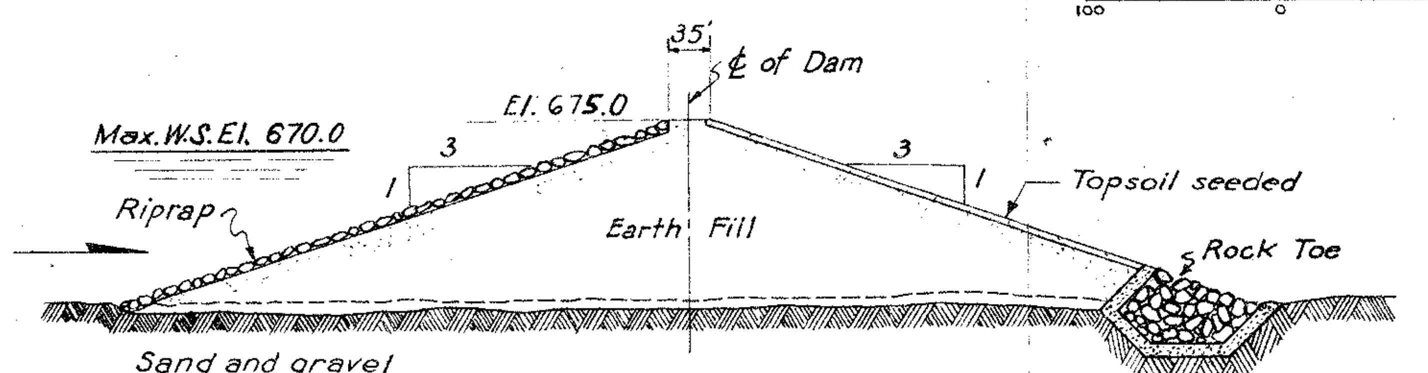
TYPICAL SECTION OF SPILLWAY

SCALE IN FEET: 30 0 30 60



SECTION OF GATE HOUSE & TUNNEL

SCALE IN FEET: 100 0 100 200



TYPICAL SECTION OF EARTH DAM

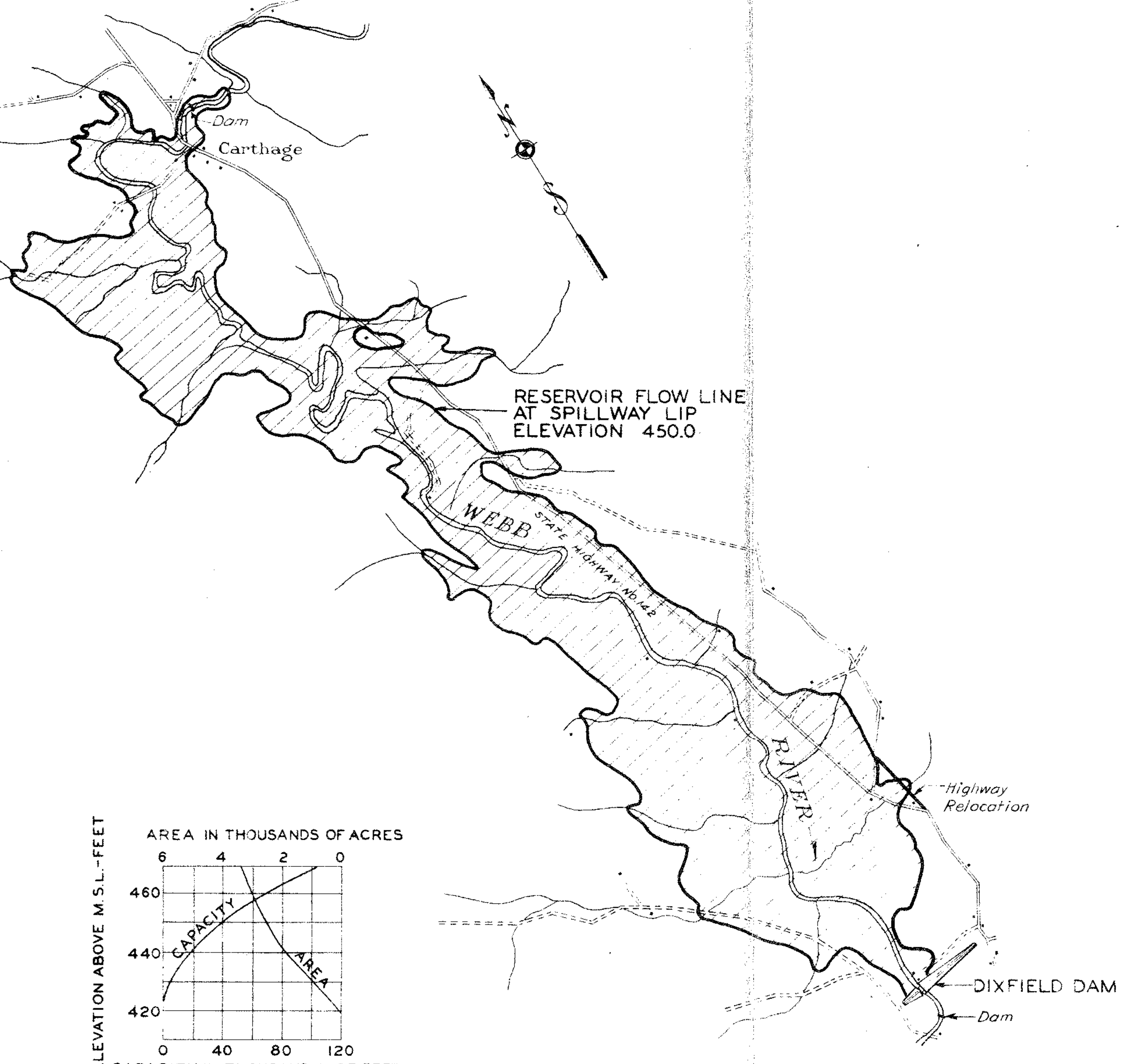
SCALE IN FEET: 100 0 100 200

Elevations on this sheet conform to U.S.G.S. datum.

ANDROSCOGGIN VALLEY FLOOD CONTROL
RUMFORD RESERVOIR
ANDROSCOGGIN RIVER
SCALE AS SHOWN
U.S. ENGINEER OFFICE, BOSTON, MASS.

SUBMITTED Frank P. Fifer PRIN. ENGINEER	APPROVED LT. COL. CORPS OF ENGINEERS
APPROVAL RECOMMENDED CAPT. CORPS OF ENGINEERS	TO ACCOMPANY REPORT DATED JUNE 30, 1938
SR. ENGINEER	TR. BY T.M.A. CK. BY J.E.A. FILE NO. A 100-9/12

FIGURE 12

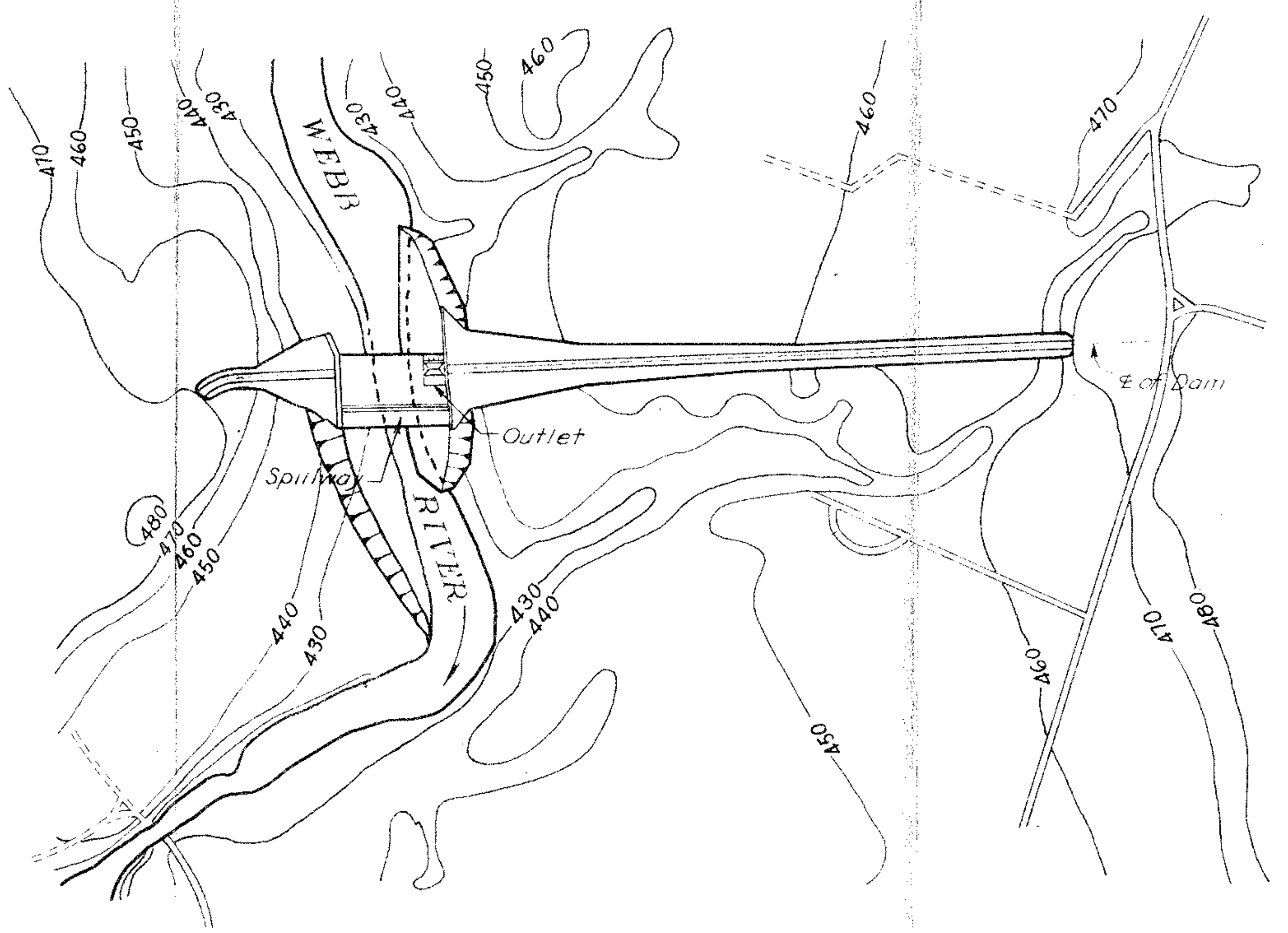


AREA AND CAPACITY CURVES

Note: Capacity of reservoir to spillway lip at El. 450 is equal to 6.0 inches of runoff over 125 square miles of area of tributary drainage basin

RESERVOIR

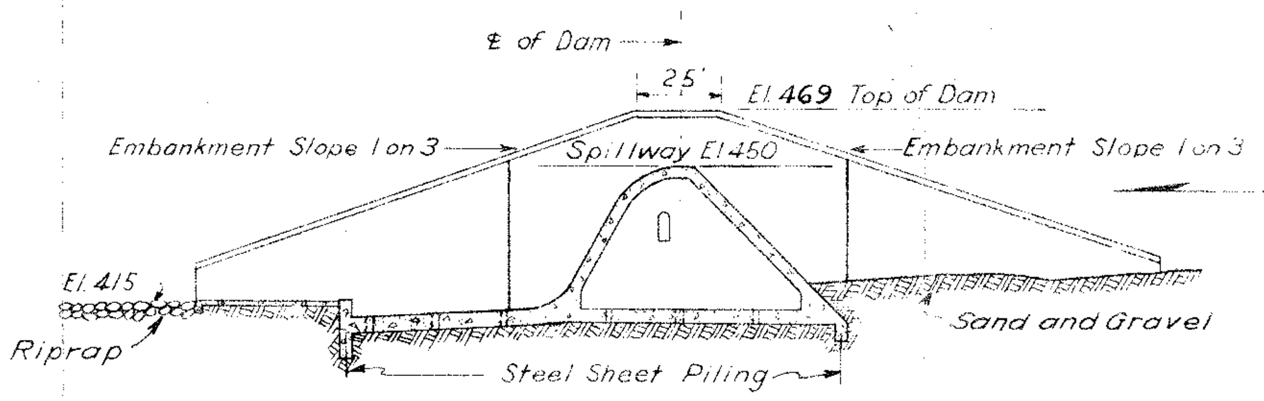
SCALE IN FEET
3000 0 3000 6000



PLAN OF DAM AND SPILLWAY

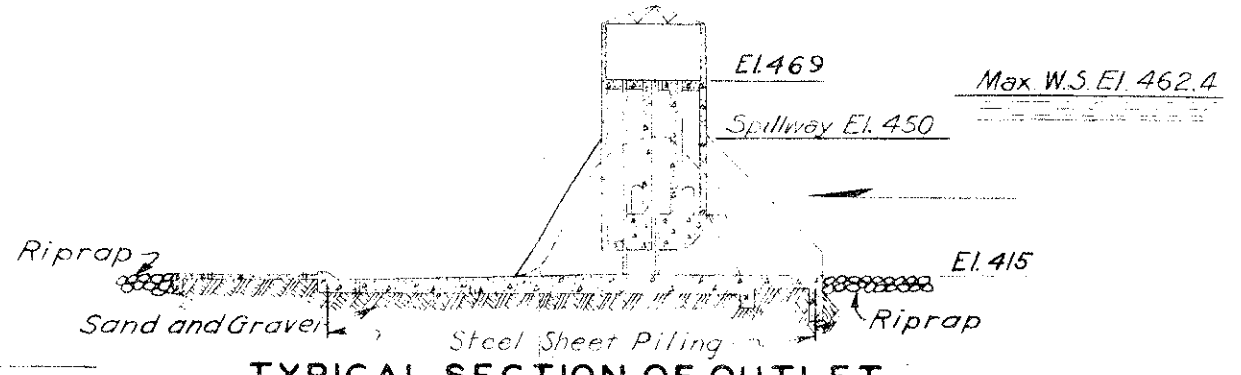
SCALE IN FEET
400 0 400 800

Note: In view of high ratio of project fixed charges to benifits foundation area was not drilled.
Foundation conditions shown on this drawing are based on geologist's field reconnaissance.
Hydraulic structures to be supported directly on sand and gravel foundation



TYPICAL SECTION OF SPILLWAY

SCALE IN FEET
50 0 50 100



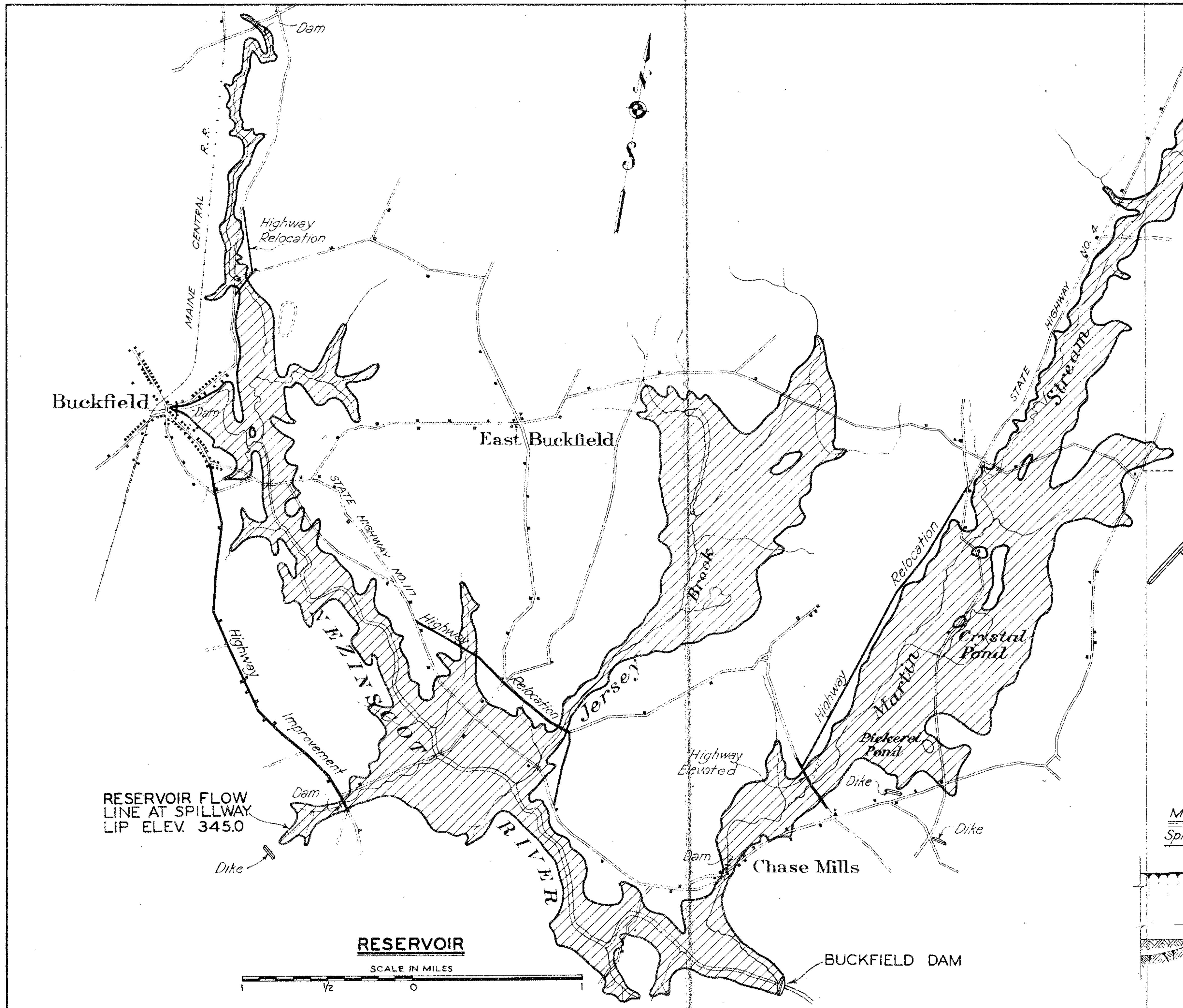
TYPICAL SECTION OF OUTLET

SCALE IN FEET
50 0 50 100

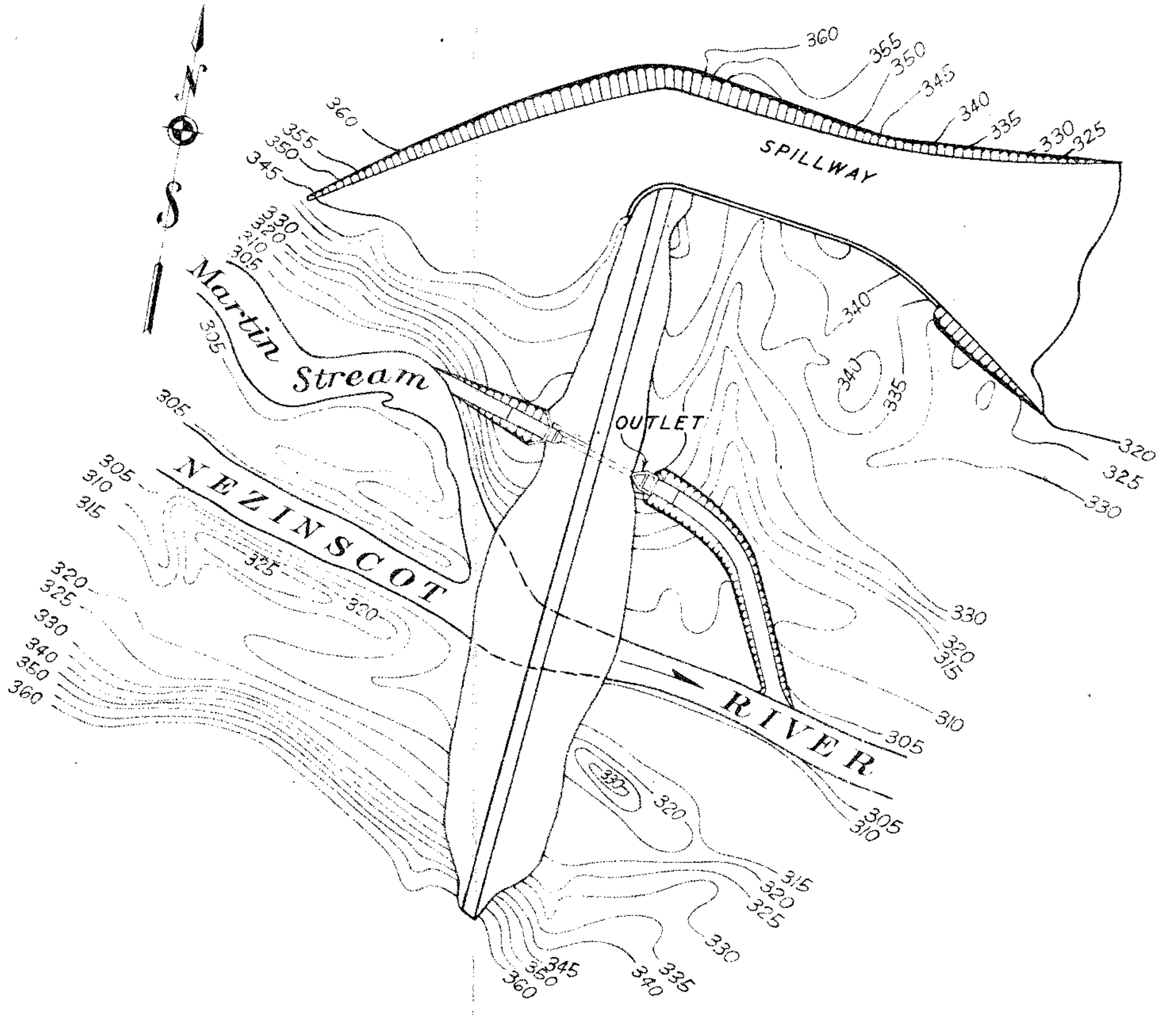
Elevations on this sheet conform to U.S.G.S. datum.

ANDROSCOGGIN VALLEY FLOOD CONTROL
DIXFIELD RESERVOIR
WEBB RIVER
SCALE AS SHOWN
U. S. ENGINEER OFFICE, BOSTON, MASS.

SUBMITTED: Frank P. Vifer, PRIN. ENGINEER	APPROVED: A. T. Bleyman, LT. COL. CORPS. OF ENGINEERS
APPROVAL RECOMMENDED: [signature], CAPT. CORPS. OF ENGINEERS	TO ACCOMPANY REPORT DATED JUNE 30, 1938
CHIEF FLOOD CONTROL DIVISION: [signature], SR. ENGINEER	TR. BY H.D.H. CK. BY J.E.A. — FILE NO. A100-9/13

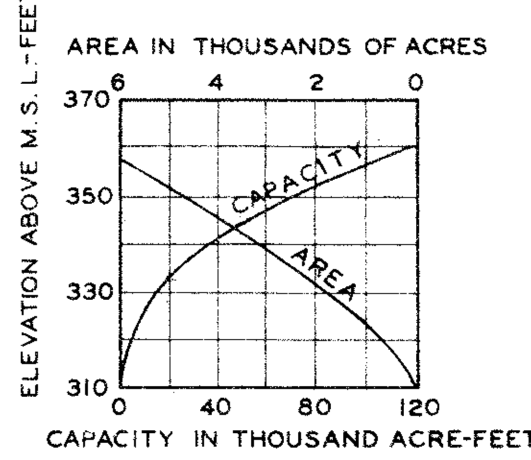


RESERVOIR

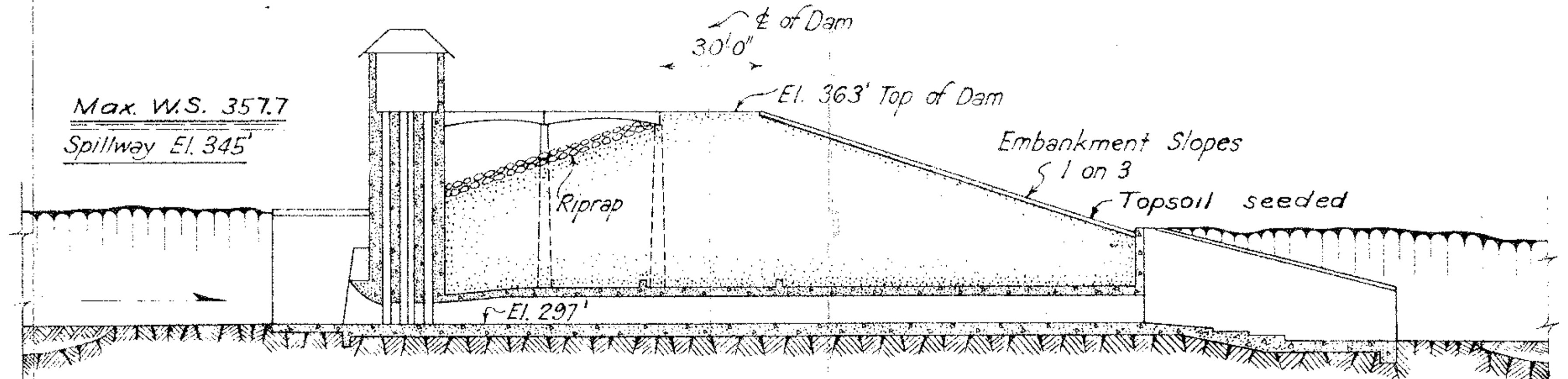


PLAN OF DAM AND SPILLWAY

Note:
In view of high ratio of project fixed charges to benefits, foundation area was not drilled. Foundation conditions shown on this drawing are based on geologists field reconnaissance.



AREA AND CAPACITY CURVES



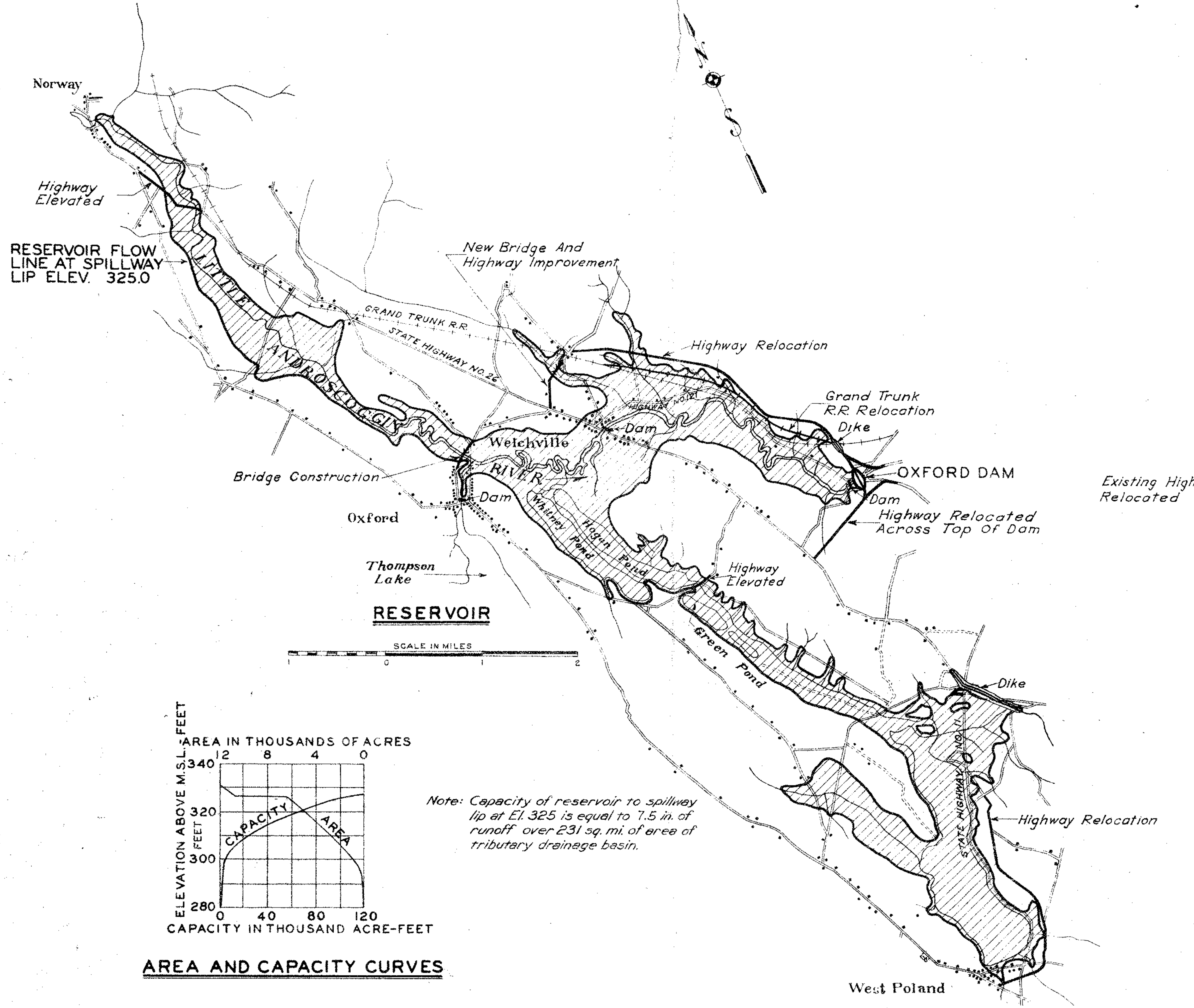
TYPICAL SECTION OF OUTLET

Note:
Capacity of reservoir to spillway lip at elevation 345 is equal to 5.9 inches runoff over 156 square miles area of tributary drainage basin.
Elevations shown on this sheet conform to U.S.G.S. datum.

ANDROSCOGGIN VALLEY FLOOD CONTROL
BUCKFIELD RESERVOIR
NEZINSCOT RIVER
SCALE AS SHOWN
U. S. ENGINEER OFFICE, BOSTON, MASS.

SUBMITTED Frank P. [illegible] PRIN. ENGINEER	APPROVED [illegible] LT. COL. CORPS OF ENGINEERS
APPROVAL RECOMMENDED Hugh [illegible] CORPS OF ENGINEERS	TO ACCOMPANY REPORT DATED JUNE 30, 1938
[illegible]	TR. BY W.A.B. CK. BY J.E.A. FILE NO. A 100-9/14

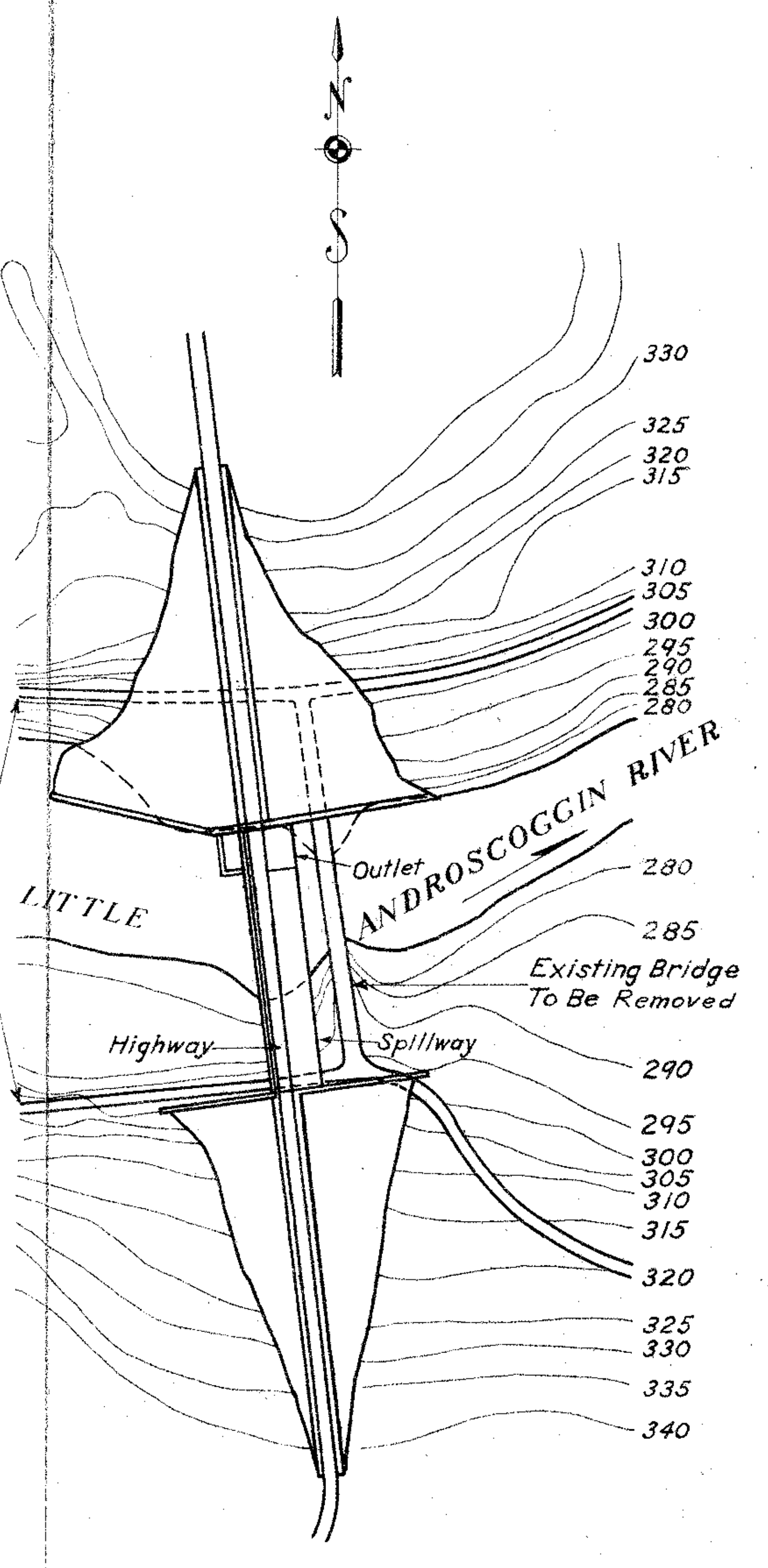
FIGURE 14



RESERVOIR

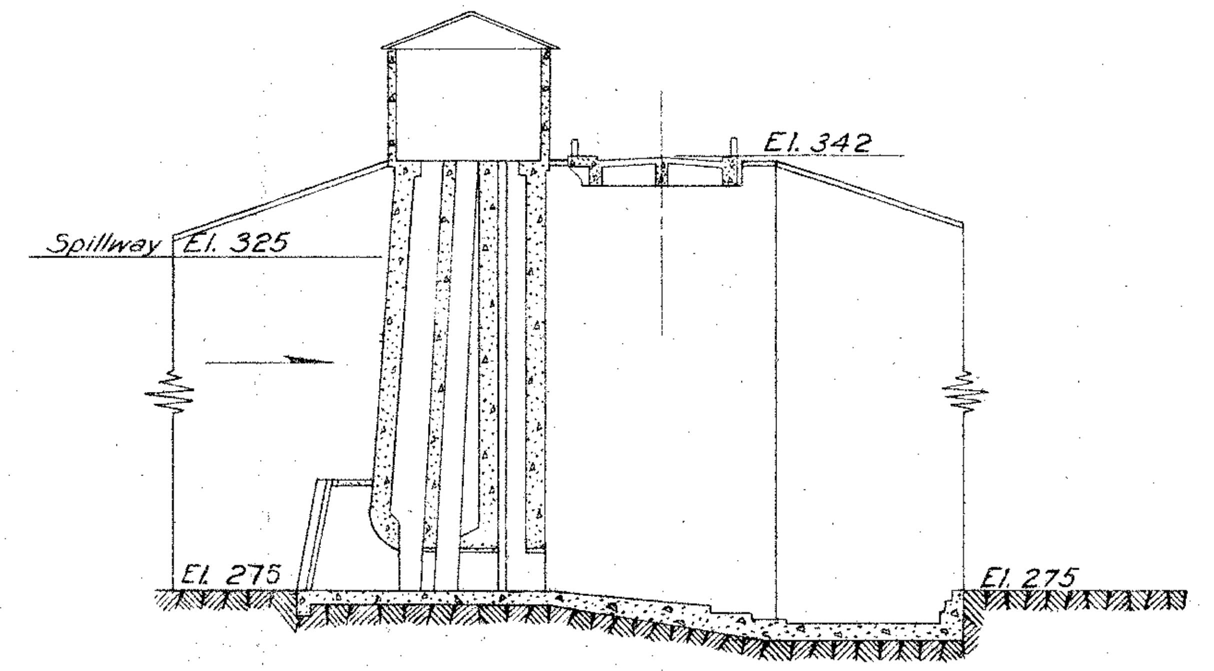
Note: Capacity of reservoir to spillway lip at El. 325 is equal to 7.5 in. of runoff over 231 sq. mi. of area of tributary drainage basin.

AREA AND CAPACITY CURVES



PLAN OF DAM AND SPILLWAY

SCALE IN FEET
200 0 200 400

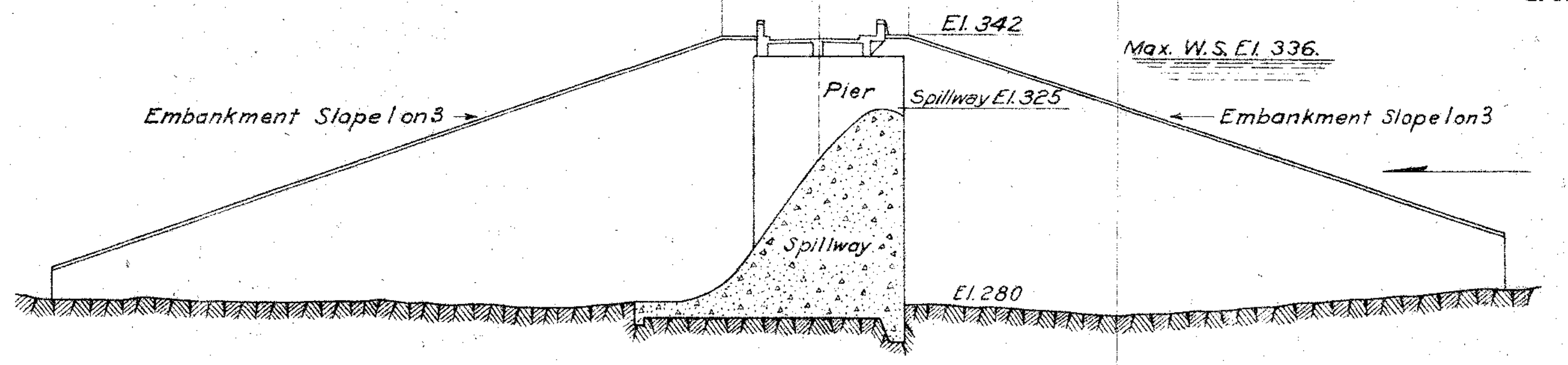


TYPICAL SECTION OF OUTLET

SCALE IN FEET
10 0 10 20 30 40

Note: In view of high ratio of project fixed charges to benefits foundation area was not drilled. Foundation conditions shown on this drawing are based on geologist's field reconnaissance. Bedrock exposed in present river channel where the concrete spillway and outlet structures are located.

Note: Elevations on this sheet conform to U.S.G.S. datum



TYPICAL SECTION OF SPILLWAY

SCALE IN FEET
10 0 10 20 30 40

ANDROSCOGGIN VALLEY FLOOD CONTROL
OXFORD RESERVOIR
LITTLE ANDROSCOGGIN RIVER
SCALE AS SHOWN

U. S. ENGINEER OFFICE, BOSTON, MASS.

SUBMITTED [signature] PRIN. ENGINEER	APPROVED [signature] LT. COL., CORPS OF ENGINEERS	
APPROVAL RECOMMENDED [signature] CAPT., CORPS OF ENGINEERS	TO ACCOMPANY REPORT DATED JUNE 30, 1938	
CHIEF FLOOD CONTROL DIVISION [signature] SR. ENGINEER	TR. BY J.F.H. CK. BY J.E.A.	FILE NO. A100-9/15

FIGURE 15

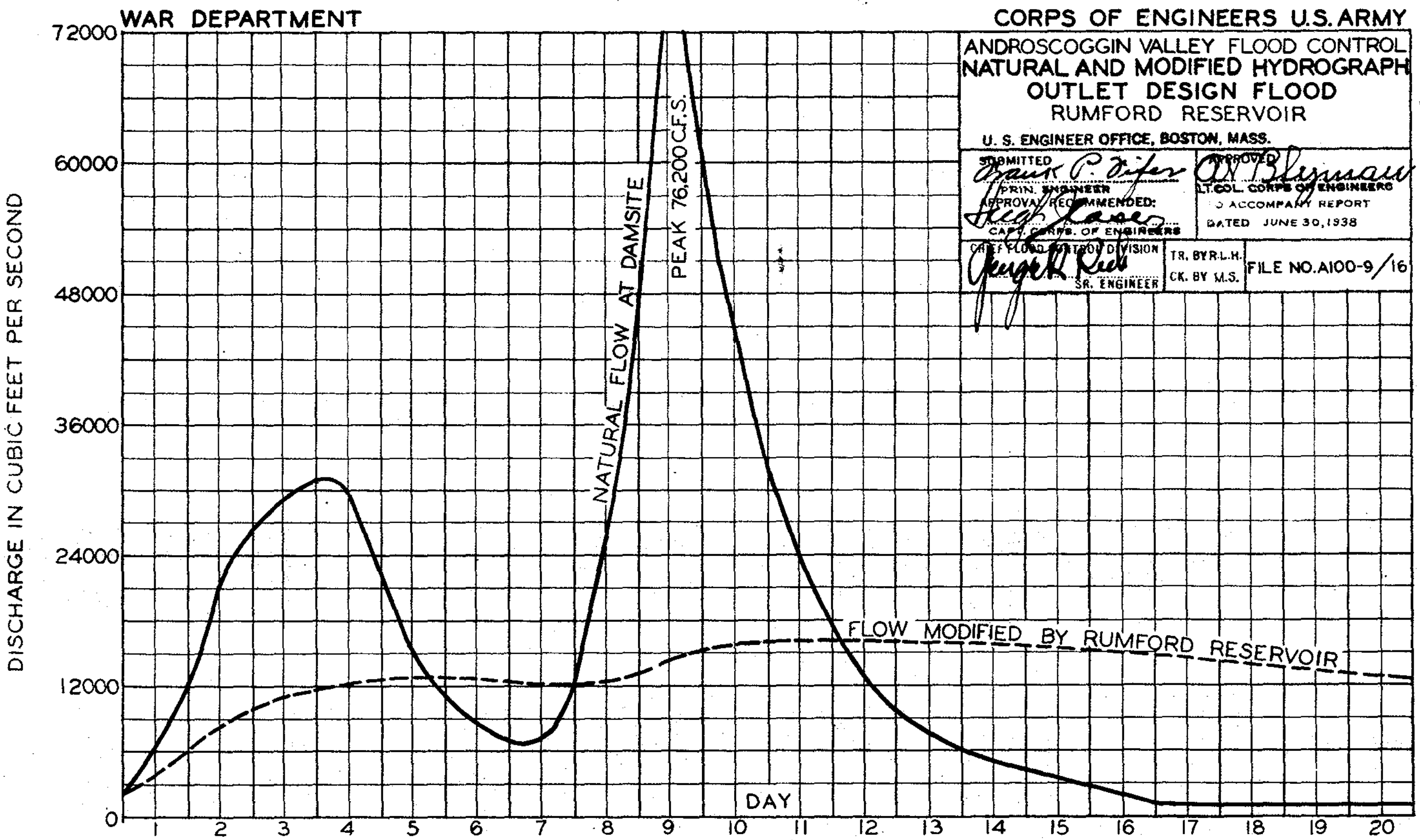

WAR DEPARTMENT
CORPS OF ENGINEERS U.S. ARMY
ANDROSCOGGIN VALLEY FLOOD CONTROL
NATURAL AND MODIFIED HYDROGRAPH
OUTLET DESIGN FLOOD
RUMFORD RESERVOIR
U. S. ENGINEER OFFICE, BOSTON, MASS.
SUBMITTED
PRIN. ENGINEER
APPROVAL RECOMMENDED:
CAPT. CORPS. OF ENGINEERS
APPROVED
LT. COL. CORPS OF ENGINEERS
TO ACCOMPANY REPORT
DATED JUNE 30, 1938
CHIEF FLOOD CONTROL DIVISION
SR. ENGINEER
TR. BY R.L.H.
CK. BY M.S.
FILE NO. A100-9/16
DISCHARGE IN CUBIC FEET PER SECOND
72000
60000
48000
36000
24000
12000
0
NATURAL FLOW AT DAMSITE
PEAK 76,200 C.F.S.
FLOW MODIFIED BY RUMFORD RESERVOIR
DAY
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

FIGURE 16

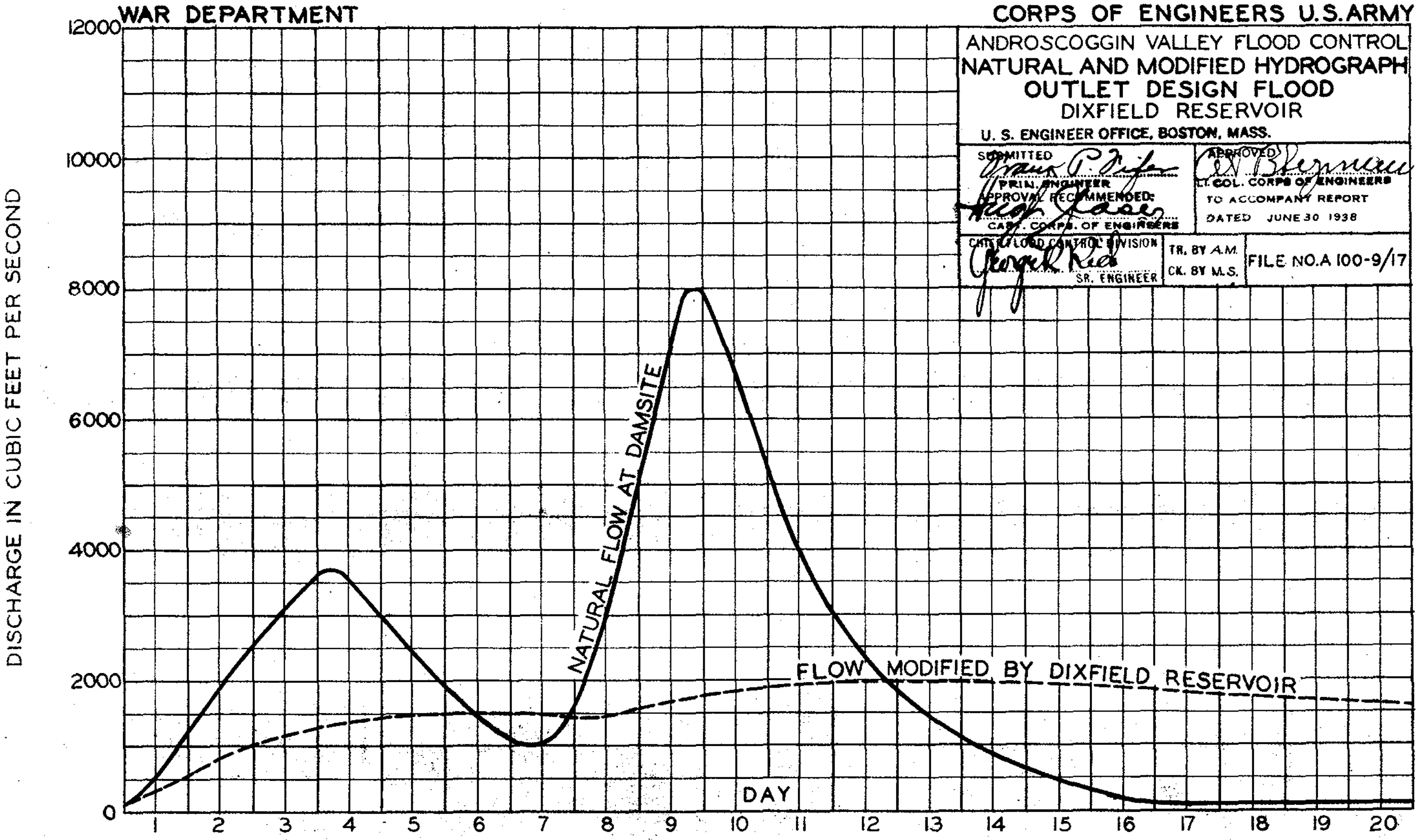

WAR DEPARTMENT
CORPS OF ENGINEERS U.S. ARMY
ANDROSCOGGIN VALLEY FLOOD CONTROL
NATURAL AND MODIFIED HYDROGRAPH
OUTLET DESIGN FLOOD
DIXFIELD RESERVOIR
U. S. ENGINEER OFFICE, BOSTON, MASS.
SUBMITTED
PRIN. ENGINEER
APPROVAL RECOMMENDED:
CAPT. CORPS. OF ENGINEERS
APPROVED
LT. COL. CORPS OF ENGINEERS
TO ACCOMPANY REPORT
DATED JUNE 30 1938
CHIEF, FLOOD CONTROL DIVISION
SR. ENGINEER
TR. BY A.M.
CK. BY M.S.
FILE NO. A 100-9/17
DISCHARGE IN CUBIC FEET PER SECOND
12000
10000
8000
6000
4000
2000
0
NATURAL FLOW AT DAMSITE
FLOW MODIFIED BY DIXFIELD RESERVOIR
DAY
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

FIGURE 17

WAR DEPARTMENT CORPS OF ENGINEERS U.S. ARMY

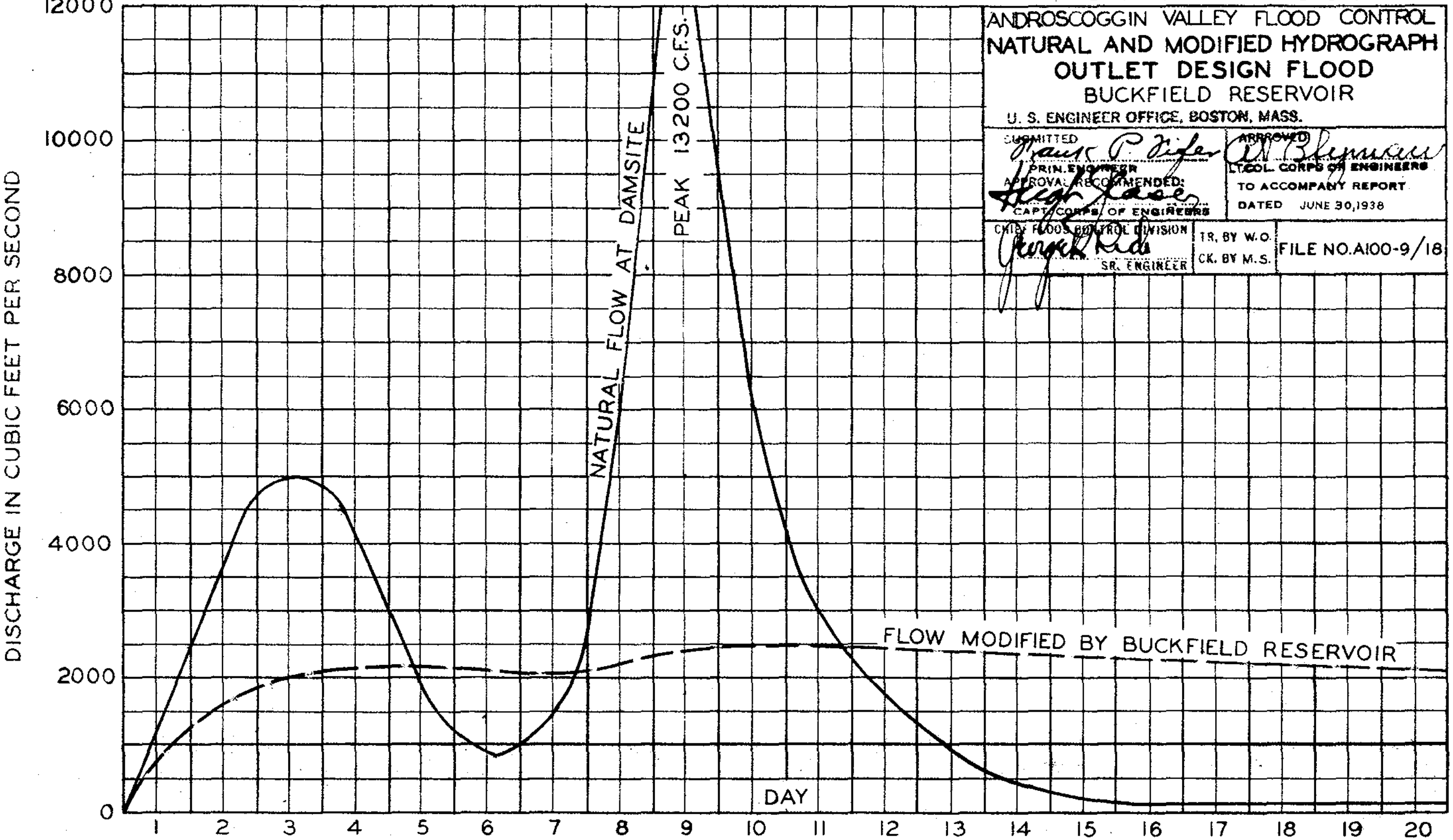


FIGURE 18

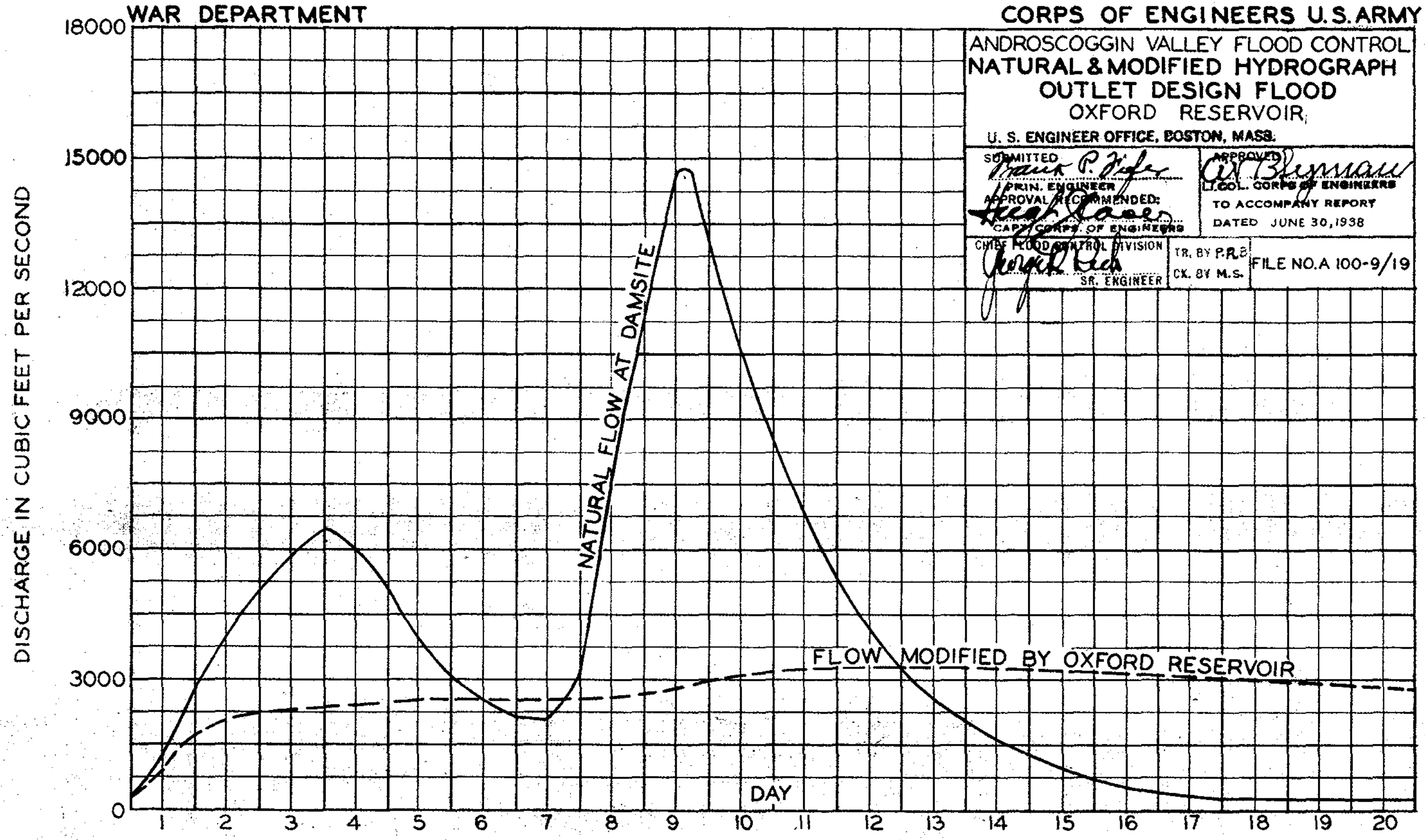

WAR DEPARTMENT
CORPS OF ENGINEERS U.S. ARMY
ANDROSCOGGIN VALLEY FLOOD CONTROL
NATURAL & MODIFIED HYDROGRAPH
OUTLET DESIGN FLOOD
OXFORD RESERVOIR
U. S. ENGINEER OFFICE, BOSTON, MASS.
SUBMITTED
PRIN. ENGINEER
APPROVAL RECOMMENDED:
CAPT. CORPS OF ENGINEERS
APPROVED
LT. COL. CORPS OF ENGINEERS
TO ACCOMPANY REPORT
DATED JUNE 30, 1938
CHIEF FLOOD CONTROL DIVISION
SR. ENGINEER
TR. BY P.R.B.
CK. BY M.S.
FILE NO. A 100-9/19
DISCHARGE IN CUBIC FEET PER SECOND
18000
15000
12000
9000
6000
3000
0
NATURAL FLOW AT DAMSITE
FLOW MODIFIED BY OXFORD RESERVOIR
DAY
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

FIGURE 19

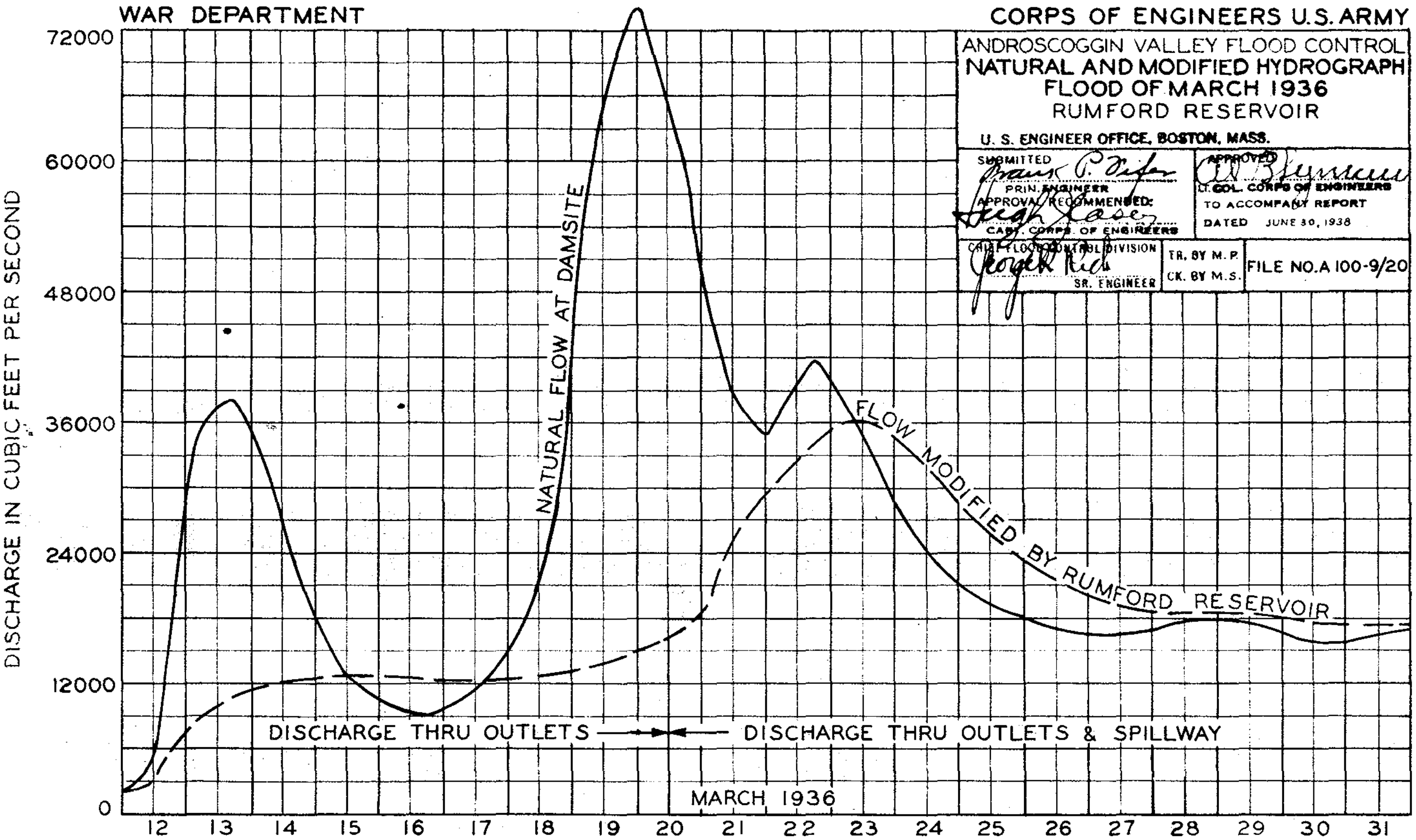

WAR DEPARTMENT
CORPS OF ENGINEERS U.S. ARMY
ANDROSCOGGIN VALLEY FLOOD CONTROL
NATURAL AND MODIFIED HYDROGRAPH
FLOOD OF MARCH 1936
RUMFORD RESERVOIR
U. S. ENGINEER OFFICE, BOSTON, MASS.
SUBMITTED
PRIN. ENGINEER
APPROVAL RECOMMENDED:
CAPT. CORPS OF ENGINEERS
APPROVED
LT. COL. CORPS OF ENGINEERS
TO ACCOMPANY REPORT
DATED JUNE 30, 1938
CHIEF FLOOD CONTROL DIVISION
SR. ENGINEER
TR. BY M. P.
CK. BY M. S.
FILE NO. A 100-9/20
DISCHARGE IN CUBIC FEET PER SECOND
72000
60000
48000
36000
24000
12000
0
NATURAL FLOW AT DAMSITE
FLOW MODIFIED BY RUMFORD RESERVOIR
DISCHARGE THRU OUTLETS
DISCHARGE THRU OUTLETS & SPILLWAY
MARCH 1936
12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

FIGURE 20

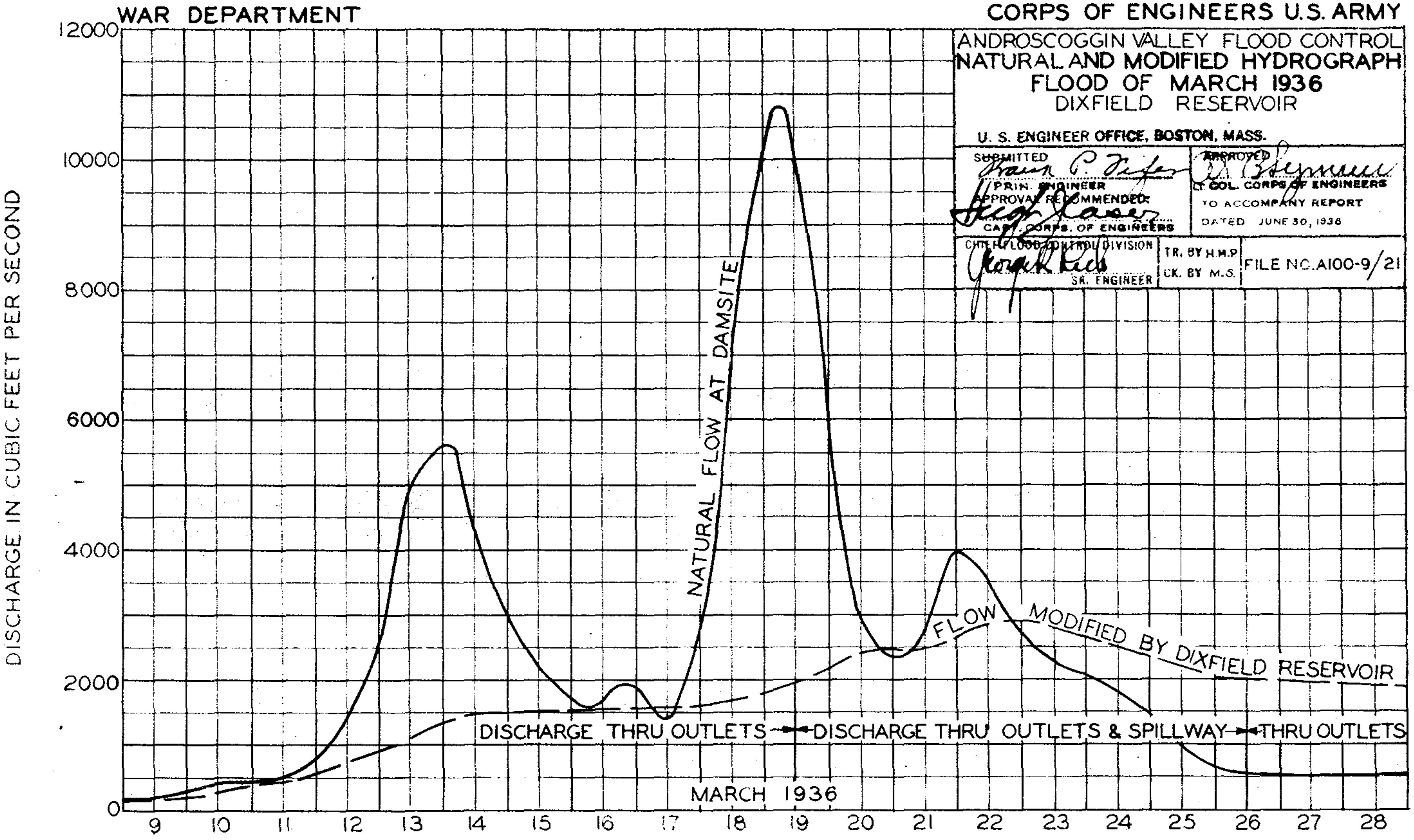

WAR DEPARTMENT
CORPS OF ENGINEERS U.S. ARMY
ANDROSCOGGIN VALLEY FLOOD CONTROL
NATURAL AND MODIFIED HYDROGRAPH
FLOOD OF MARCH 1936
DIXFIELD RESERVOIR
U. S. ENGINEER OFFICE, BOSTON, MASS.
SUBMITTED
PRIN. ENGINEER
APPROVAL RECOMMENDED:
CAPT. CORPS. OF ENGINEERS
APPROVED
LT. COL. CORPS OF ENGINEERS
TO ACCOMPANY REPORT
DATED JUNE 30, 1936
CHIEF FLOOD CONTROL DIVISION
SR. ENGINEER
TR. BY H.M.P.
CK. BY M.S.
FILE NO. A100-9/21
DISCHARGE IN CUBIC FEET PER SECOND
12000
10000
8000
6000
4000
2000
0
NATURAL FLOW AT DAMSITE
FLOW MODIFIED BY DIXFIELD RESERVOIR
DISCHARGE THRU OUTLETS
DISCHARGE THRU OUTLETS & SPILLWAY
THRU OUTLETS
MARCH 1936
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28

FIGURE 21

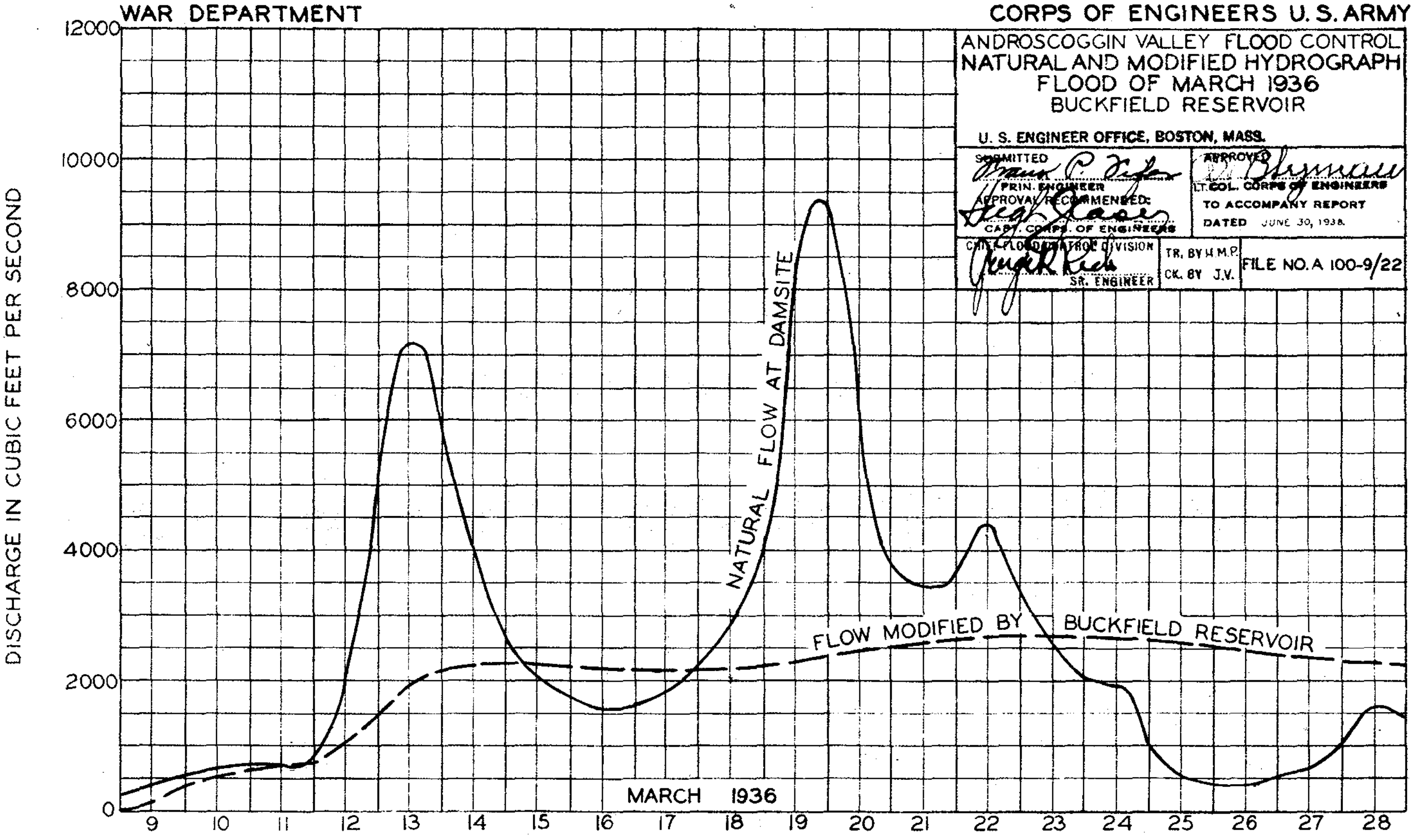

WAR DEPARTMENT
CORPS OF ENGINEERS U.S. ARMY
ANDROSCOGGIN VALLEY FLOOD CONTROL
NATURAL AND MODIFIED HYDROGRAPH
FLOOD OF MARCH 1936
BUCKFIELD RESERVOIR
U. S. ENGINEER OFFICE, BOSTON, MASS.
SUBMITTED
PRIN. ENGINEER
APPROVAL RECOMMENDED:
CAPT. CORPS. OF ENGINEERS
APPROVED
LT. COL. CORPS OF ENGINEERS
TO ACCOMPANY REPORT
DATED JUNE 30, 1938.
CHIEF FLOOD CONTROL DIVISION
SR. ENGINEER
TR. BY H.M.P.
CK. BY J.V.
FILE NO. A 100-9/22
DISCHARGE IN CUBIC FEET PER SECOND
12000
10000
8000
6000
4000
2000
0
NATURAL FLOW AT DAMSITE
FLOW MODIFIED BY BUCKFIELD RESERVOIR
MARCH 1936
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28

FIGURE 22

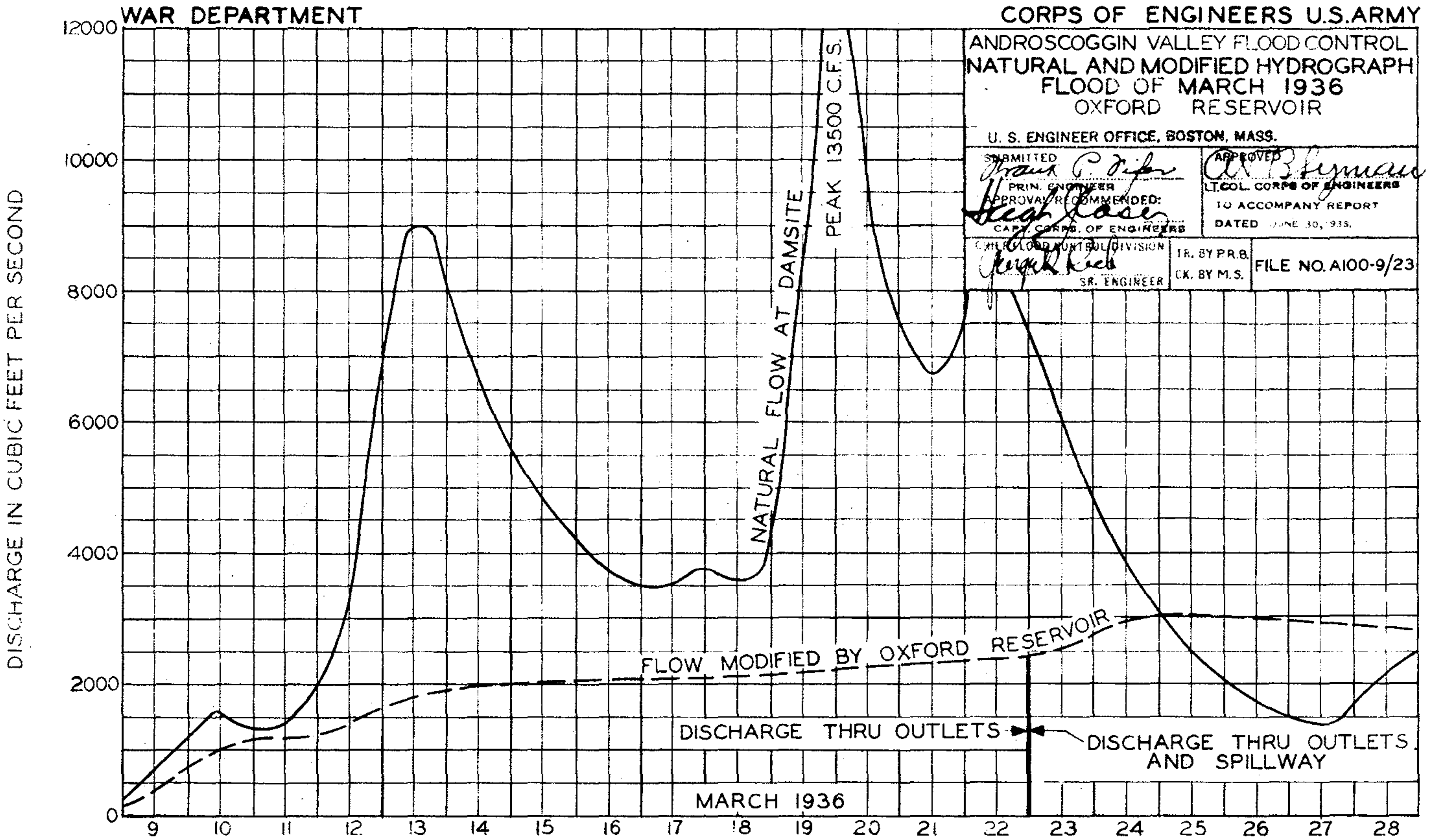
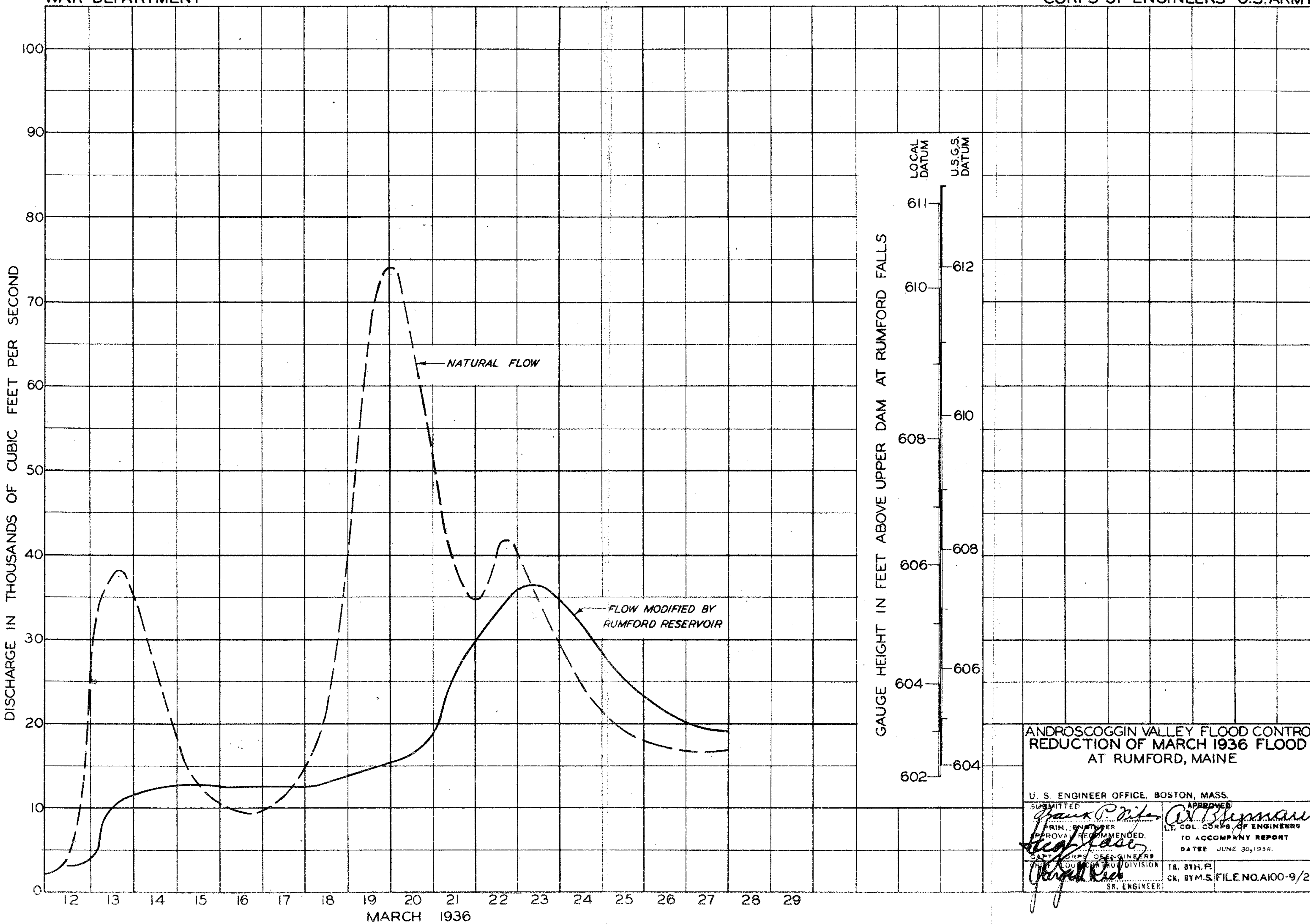

WAR DEPARTMENT
CORPS OF ENGINEERS U.S.ARMY
ANDROSCOGGIN VALLEY FLOOD CONTROL
NATURAL AND MODIFIED HYDROGRAPH
FLOOD OF MARCH 1936
OXFORD RESERVOIR
U. S. ENGINEER OFFICE, BOSTON, MASS.
SUBMITTED
PRIN. ENGINEER
APPROVAL RECOMMENDED:
CAPT. CORPS. OF ENGINEERS
APPROVED
LT.COL. CORPS OF ENGINEERS
TO ACCOMPANY REPORT
DATED
CHIEF FLOOD CONTROL DIVISION
SR. ENGINEER
TR. BY P.R.B.
CK. BY M.S.
FILE NO. A100-9/23
DISCHARGE IN CUBIC FEET PER SECOND
12000
10000
8000
6000
4000
2000
0
NATURAL FLOW AT DAMSITE
PEAK 13500 C.F.S.
FLOW MODIFIED BY OXFORD RESERVOIR
DISCHARGE THRU OUTLETS
DISCHARGE THRU OUTLETS AND SPILLWAY
MARCH 1936
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28

FIGURE 23



ANDROSCOGGIN VALLEY FLOOD CONTROL
REDUCTION OF MARCH 1936 FLOOD
AT RUMFORD, MAINE

U. S. ENGINEER OFFICE, BOSTON, MASS.

SUBMITTED	APPROVED
Frank P. Nifer PRIN. ENGINEER APPROVAL RECOMMENDED. Hugh Case CAPT. CORPS OF ENGINEERS CHIEF FLOOD CONTROL DIVISION Harold Reed SR. ENGINEER	A.V. Bleyman LT. COL. CORPS OF ENGINEERS TO ACCOMPANY REPORT DATED JUNE 30, 1938. TR. BY H.P. CK. BY M.S. FILE NO. A100-9/24

FIGURE 24

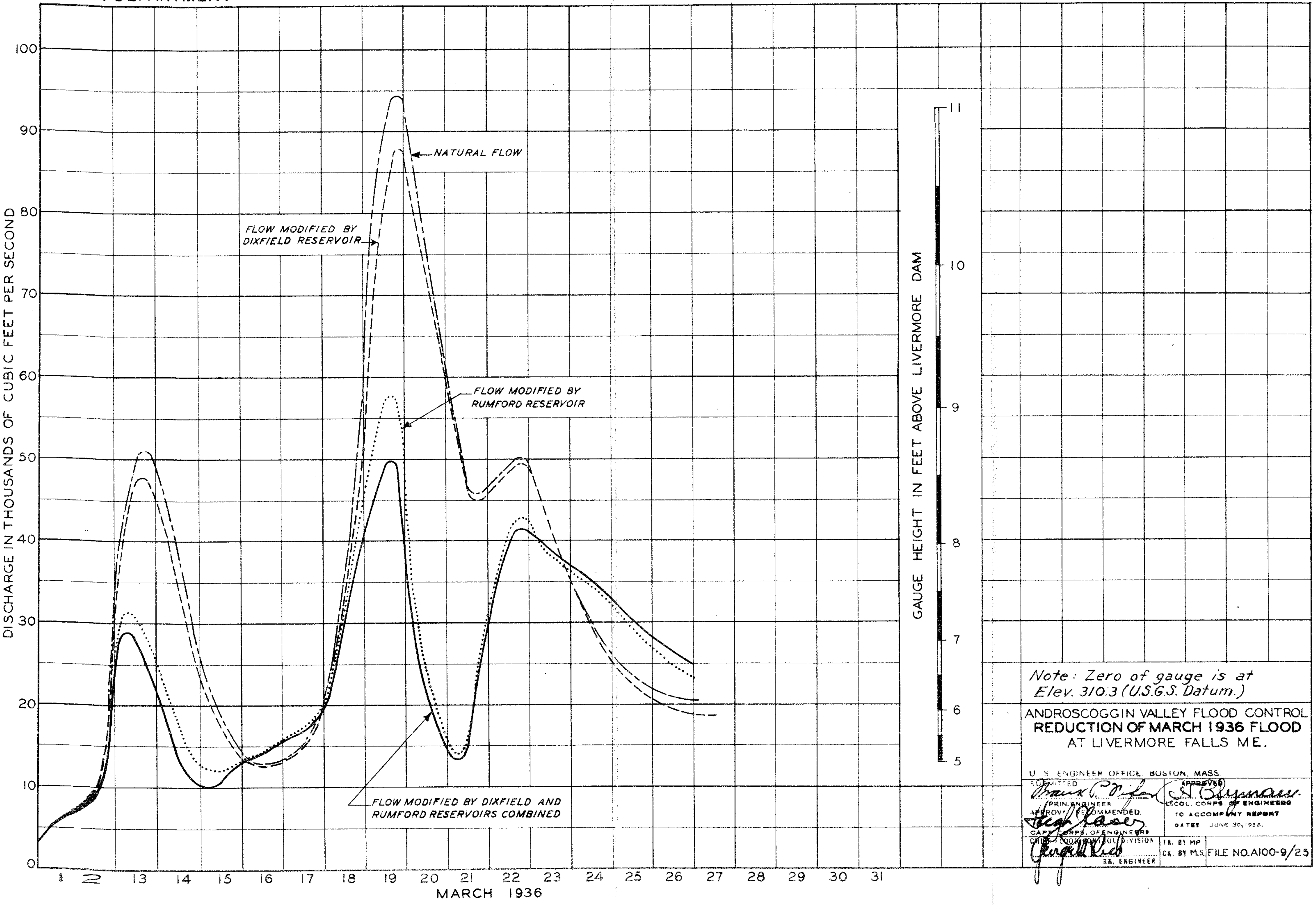

DISCHARGE IN THOUSANDS OF CUBIC FEET PER SECOND
0
10
20
30
40
50
60
70
80
90
100
NATURAL FLOW
FLOW MODIFIED BY DIXFIELD RESERVOIR
FLOW MODIFIED BY RUMFORD RESERVOIR
FLOW MODIFIED BY DIXFIELD AND RUMFORD RESERVOIRS COMBINED
1 2 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
MARCH 1936
GAUGE HEIGHT IN FEET ABOVE LIVERMORE DAM
5
6
7
8
9
10
11
Note: Zero of gauge is at Elev. 310.3 (U.S.G.S. Datum.)
ANDROSCOGGIN VALLEY FLOOD CONTROL
REDUCTION OF MARCH 1936 FLOOD
AT LIVERMORE FALLS ME.
U. S. ENGINEER OFFICE, BOSTON, MASS.
SUBMITTED
PRIN. ENGINEER
APPROVAL RECOMMENDED.
CAPT. CORPS. OF ENGINEERS
CHIEF FLOOD CONTROL DIVISION
SR. ENGINEER
APPROVED
LT.COL. CORPS. OF ENGINEERS
TO ACCOMPANY REPORT
DATED JUNE 30, 1938.
TR. BY MP
CK. BY M.S.
FILE NO. A100-9/25

FIGURE 25

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY

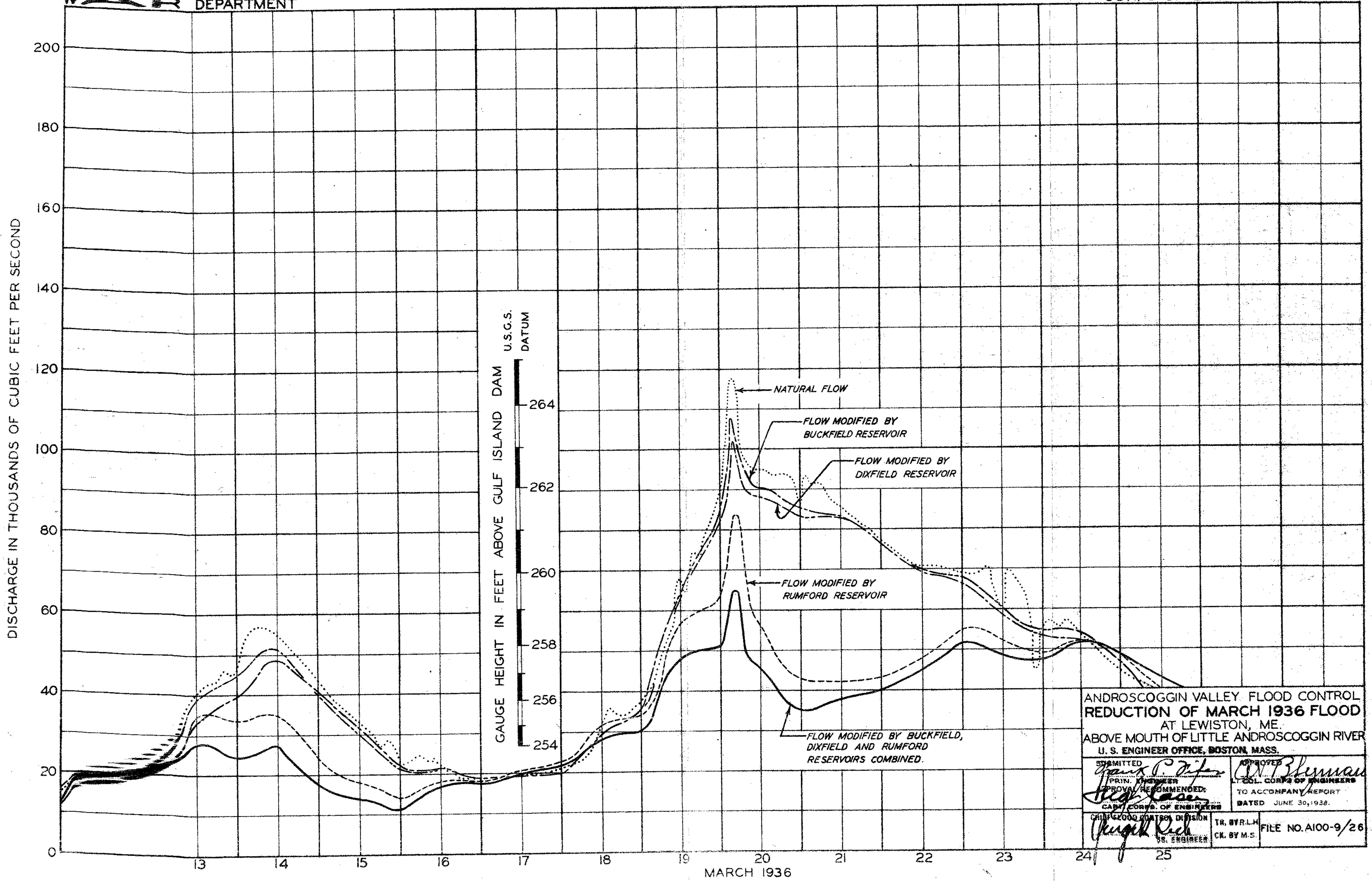


FIGURE 26

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY

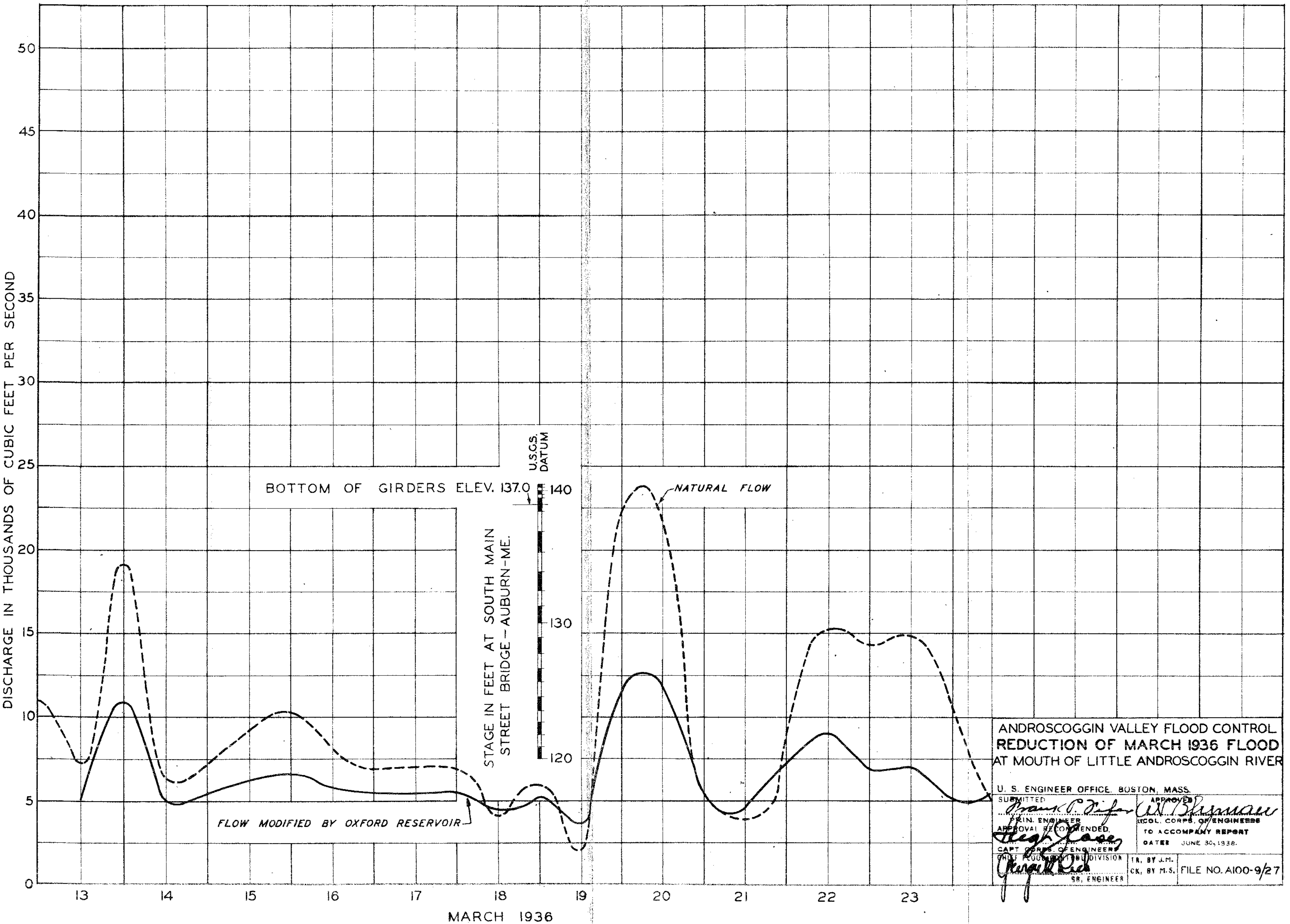


FIGURE 27

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY

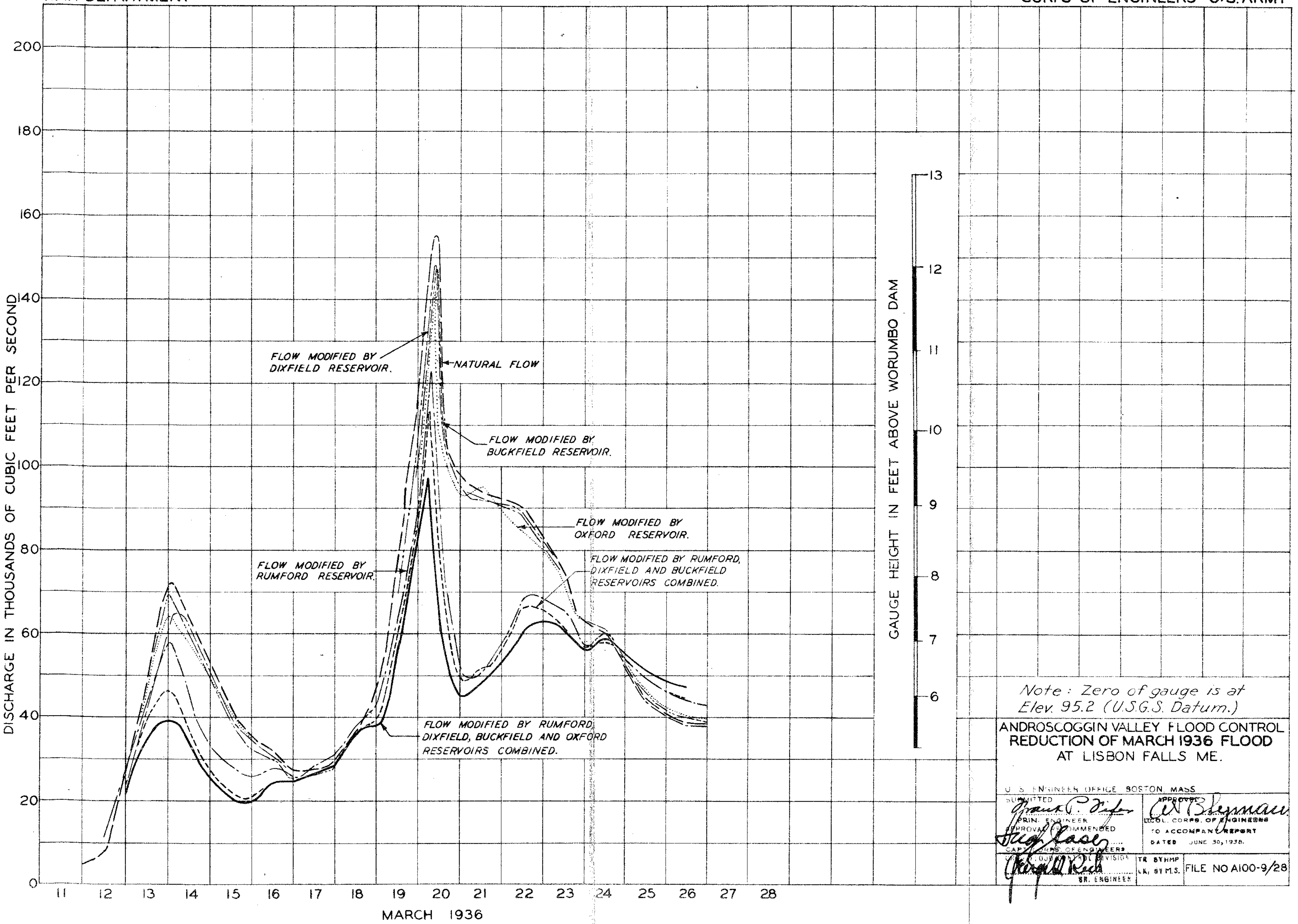


FIGURE 28

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

ANDROSCOGGIN VALLEY FLOOD CONTROL
NATURAL AND MODIFIED PROFILE
FLOOD OF MARCH 1936
SHEET 1 OF 2 SHEETS
U. S. ENGINEER OFFICE, BOSTON, MASS.

SUBMITTED: Frank P. Miller, PRIN. ENGINEER
APPROVED: A. B. Jones, LT. COL. CORPS OF ENGINEERS
APPROVAL RECOMMENDED: CAPT. CORPS OF ENGINEERS; CHIEF FLOOD CONTROL DIVISION; SR. ENGINEER
TO ACCOMPANY REPORT DATED JUNE 30, 1938
TR. BY E.J.R. CK. BY M.S.
FILE NO. A100-9/29

FIGURE 29

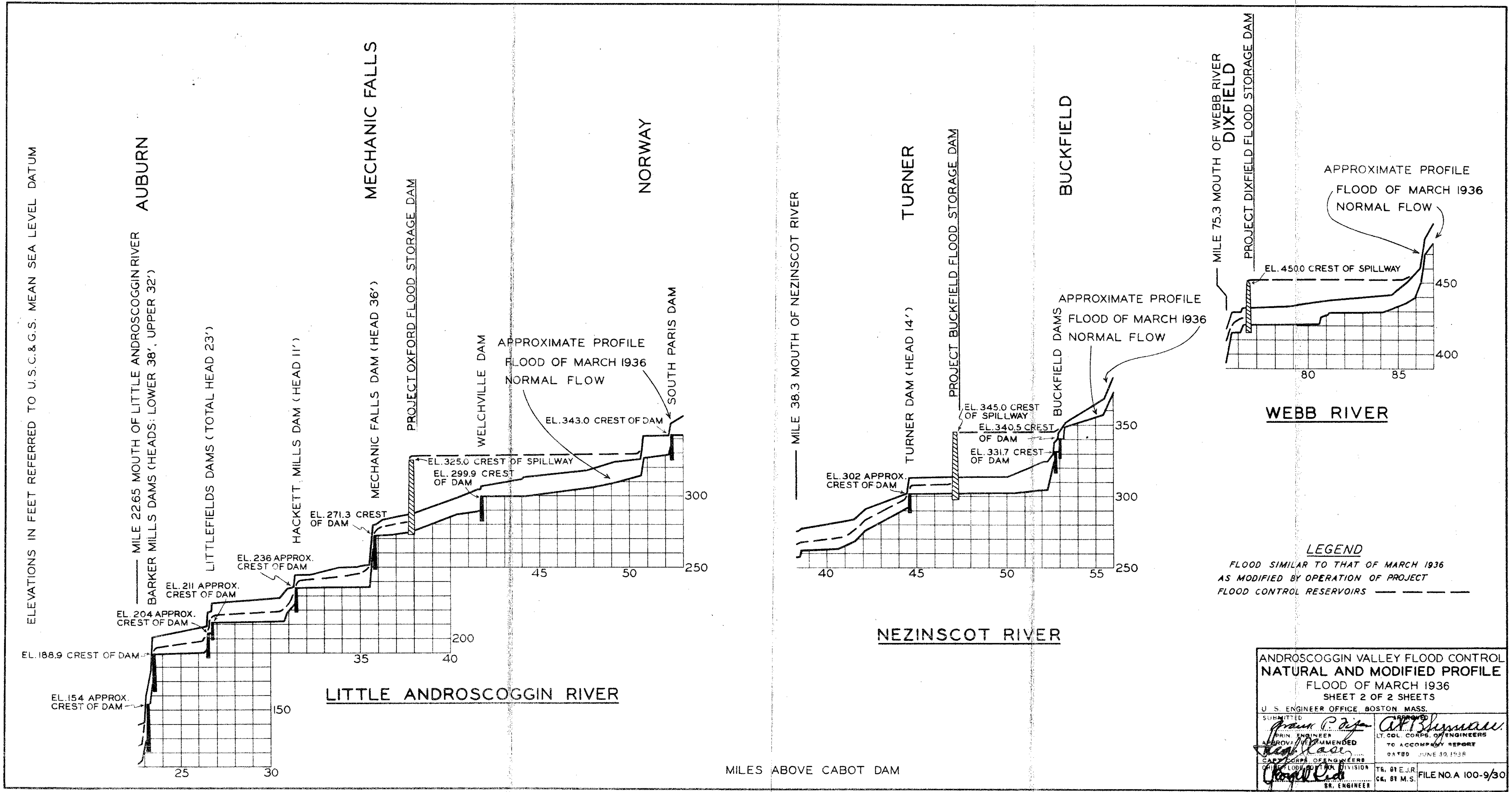

ELEVATIONS IN FEET REFERRED TO U.S.C.&G.S. MEAN SEA LEVEL DATUM
AUBURN
MILE 22.65 MOUTH OF LITTLE ANDROSCOGGIN RIVER
BARKER MILLS DAMS (HEADS: LOWER 38', UPPER 32')
LITTLEFIELDS DAMS (TOTAL HEAD 23')
HACKETT MILLS DAM (HEAD 11')
MECHANIC FALLS
MECHANIC FALLS DAM (HEAD 36')
PROJECT OXFORD FLOOD STORAGE DAM
WELCHVILLE DAM
NORWAY
SOUTH PARIS DAM
APPROXIMATE PROFILE
FLOOD OF MARCH 1936
NORMAL FLOW
EL. 343.0 CREST OF DAM
EL. 325.0 CREST OF SPILLWAY
EL. 299.9 CREST OF DAM
EL. 271.3 CREST OF DAM
EL. 236 APPROX. CREST OF DAM
EL. 211 APPROX. CREST OF DAM
EL. 204 APPROX. CREST OF DAM
EL. 188.9 CREST OF DAM
EL. 154 APPROX. CREST OF DAM
LITTLE ANDROSCOGGIN RIVER
MILE 38.3 MOUTH OF NEZINSCOT RIVER
TURNER
TURNER DAM (HEAD 14')
PROJECT BUCKFIELD FLOOD STORAGE DAM
BUCKFIELD
BUCKFIELD DAMS
EL. 302 APPROX. CREST OF DAM
EL. 345.0 CREST OF SPILLWAY
EL. 340.5 CREST OF DAM
EL. 331.7 CREST OF DAM
NEZINSCOT RIVER
MILE 75.3 MOUTH OF WEBB RIVER
DIXFIELD
PROJECT DIXFIELD FLOOD STORAGE DAM
EL. 450.0 CREST OF SPILLWAY
WEBB RIVER
LEGEND
FLOOD SIMILAR TO THAT OF MARCH 1936 AS MODIFIED BY OPERATION OF PROJECT FLOOD CONTROL RESERVOIRS
MILES ABOVE CABOT DAM
ANDROSCOGGIN VALLEY FLOOD CONTROL
NATURAL AND MODIFIED PROFILE
FLOOD OF MARCH 1936
SHEET 2 OF 2 SHEETS
U. S. ENGINEER OFFICE, BOSTON, MASS.
SUBMITTED
PRIN. ENGINEER
APPROVAL RECOMMENDED
CAPT. CORPS OF ENGINEERS
CHIEF, FLOOD CONTROL DIVISION
SR. ENGINEER
APPROVED
LT. COL. CORPS OF ENGINEERS
TO ACCOMPANY REPORT
DATED JUNE 30, 1938
T6, 61 E.J.R.
C6, 61 M.S.
FILE NO. A 100-9/30

FIGURE 30

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY

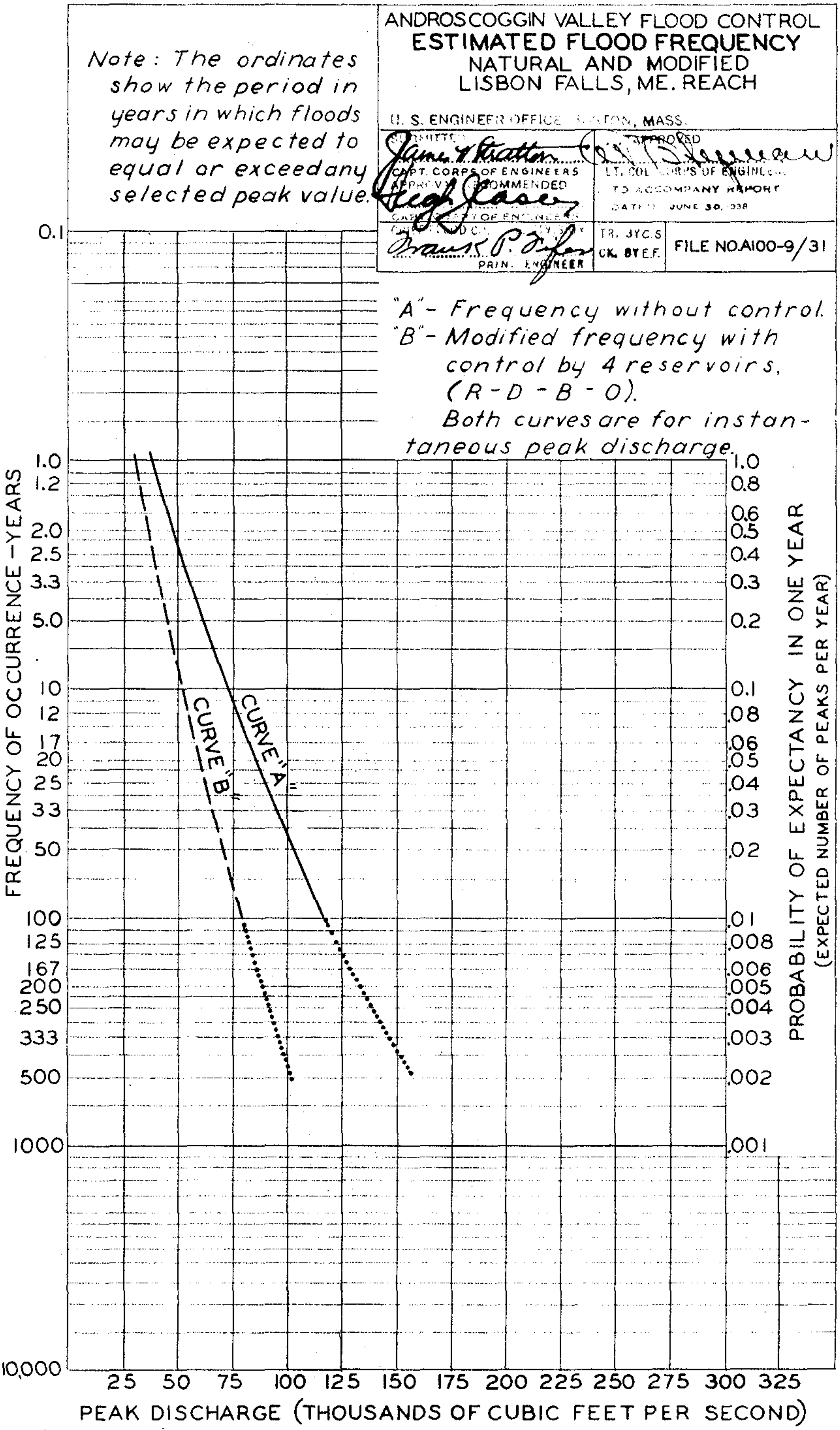
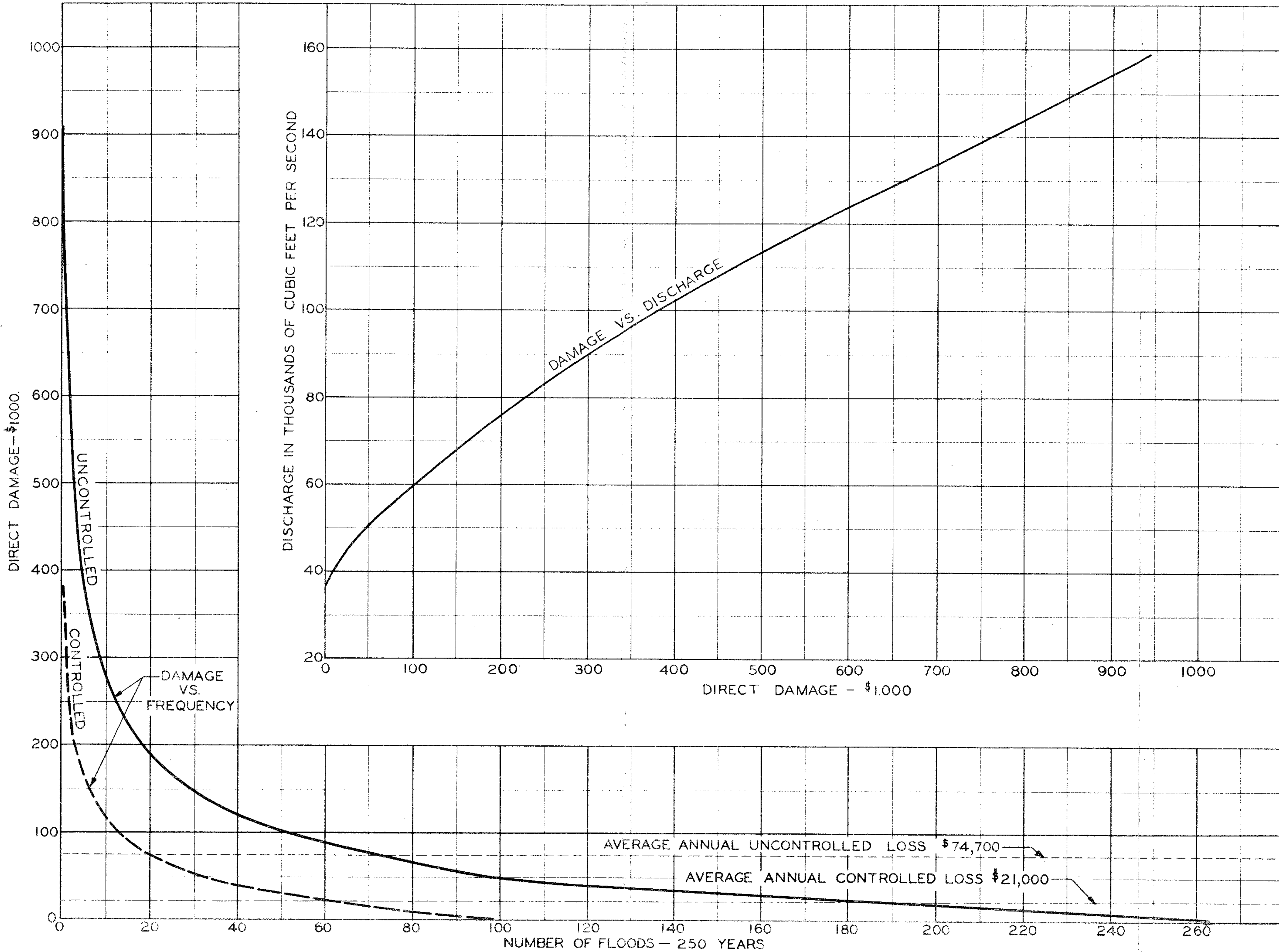


FIGURE 31

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY



Note:
Modified damage-frequency curve is based on control by 4 reservoirs, (R-D-B-O).
Curves are based on direct damage only. Total annual loss, direct and indirect = 1.480x direct.

ANDROSCOGGIN VALLEY FLOOD CONTROL
FLOOD DAMAGES
NATURAL AND MODIFIED
LISBON FALLS, ME., REACH

U. S. ENGINEER OFFICE, BOSTON, MASS.

SUBMITTED ... CAPT. CORPS OF ENGINEERS	APPROVED ... LT. COL. CORPS OF ENGINEERS	
APPROVAL RECOMMENDED ... CAPT. CORPS OF ENGINEERS	TO ACCOMPANY REPORT DATED JUNE 30, 1938	
CHIEF FLOOD CONTROL DIVISION ... PRIN. ENGINEER	TR. BY PB / CK. BY EE	FILE NO. A100-9/32

FIGURE 32

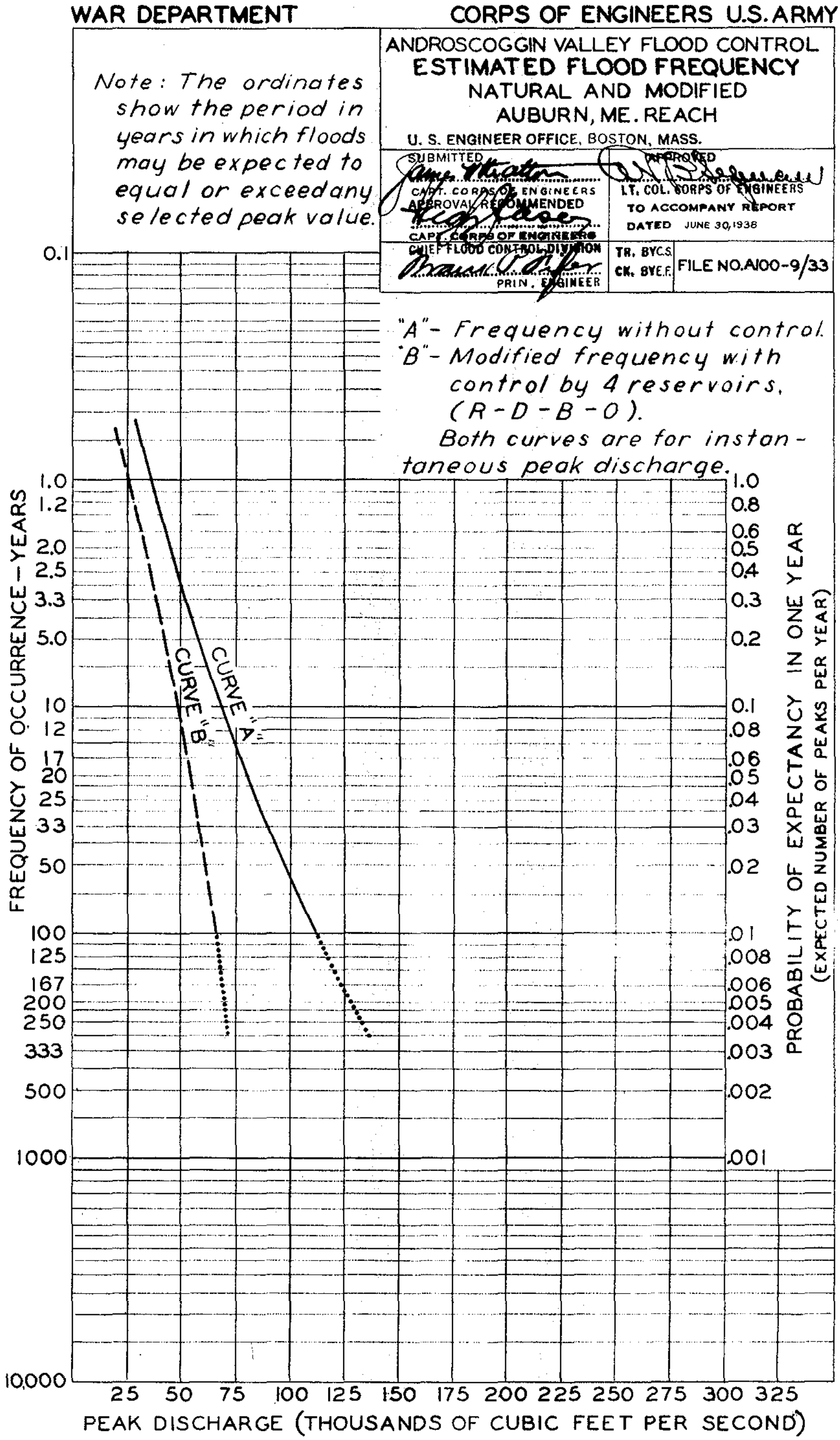
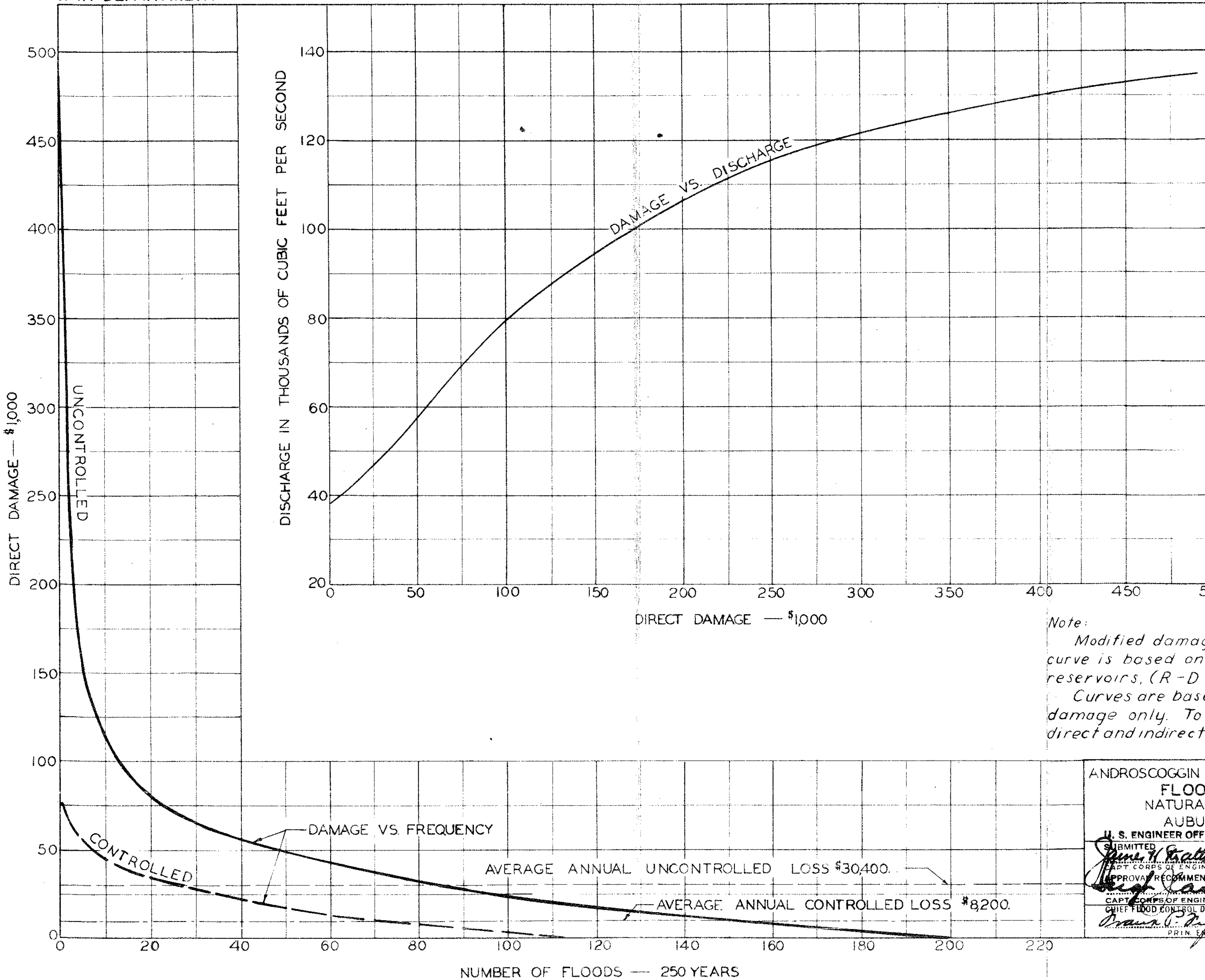

WAR DEPARTMENT
CORPS OF ENGINEERS U.S. ARMY
ANDROSCOGGIN VALLEY FLOOD CONTROL
ESTIMATED FLOOD FREQUENCY
NATURAL AND MODIFIED
AUBURN, ME. REACH
U. S. ENGINEER OFFICE, BOSTON, MASS.
SUBMITTED
CAPT. CORPS OF ENGINEERS
APPROVAL RECOMMENDED
CAPT. CORPS OF ENGINEERS
CHIEF FLOOD CONTROL DIVISION
PRIN. ENGINEER
APPROVED
LT. COL. CORPS OF ENGINEERS
TO ACCOMPANY REPORT
DATED JUNE 30, 1938
TR. BY C.S.
CK. BY E.F.
FILE NO. A100-9/33
Note: The ordinates show the period in years in which floods may be expected to equal or exceed any selected peak value.
"A" - Frequency without control.
"B" - Modified frequency with control by 4 reservoirs, (R-D-B-O).
Both curves are for instantaneous peak discharge.
CURVE "A"
CURVE "B"
FREQUENCY OF OCCURRENCE - YEARS
0.1
1.0
1.2
2.0
2.5
3.3
5.0
10
12
17
20
25
33
50
100
125
167
200
250
333
500
1000
10,000
PROBABILITY OF EXPECTANCY IN ONE YEAR
(EXPECTED NUMBER OF PEAKS PER YEAR)
1.0
0.8
0.6
0.5
0.4
0.3
0.2
0.1
.08
.06
.05
.04
.03
.02
.01
.008
.006
.005
.004
.003
.002
.001
25 50 75 100 125 150 175 200 225 250 275 300 325
PEAK DISCHARGE (THOUSANDS OF CUBIC FEET PER SECOND)

FIGURE 33



Note:
Modified damage-frequency curve is based on control by 4 reservoirs, (R-D -B -O).
Curves are based on direct damage only. Total annual loss, direct and indirect = 1.702 x direct.

ANDROSCOGGIN VALLEY FLOOD CONTROL
FLOOD DAMAGES
NATURAL AND MODIFIED
AUBURN, ME., REACH
U. S. ENGINEER OFFICE, BOSTON, MASS.

SUBMITTED	APPROVED
CAPT. CORPS OF ENGINEERS	LT. COL. CORPS OF ENGINEERS
APPROVAL RECOMMENDED	TO ACCOMPANY REPORT
CAPT. CORPS OF ENGINEERS	DATED JUNE 30, 1938
CHIEF FLOOD CONTROL DIVISION	TR. BY H.C. / CK. BY E.F. / FILE NO. A100-9/34
PRIN. ENGINEER	

FIGURE 34

WAR DEPARTMENT CORPS OF ENGINEERS U.S. ARMY

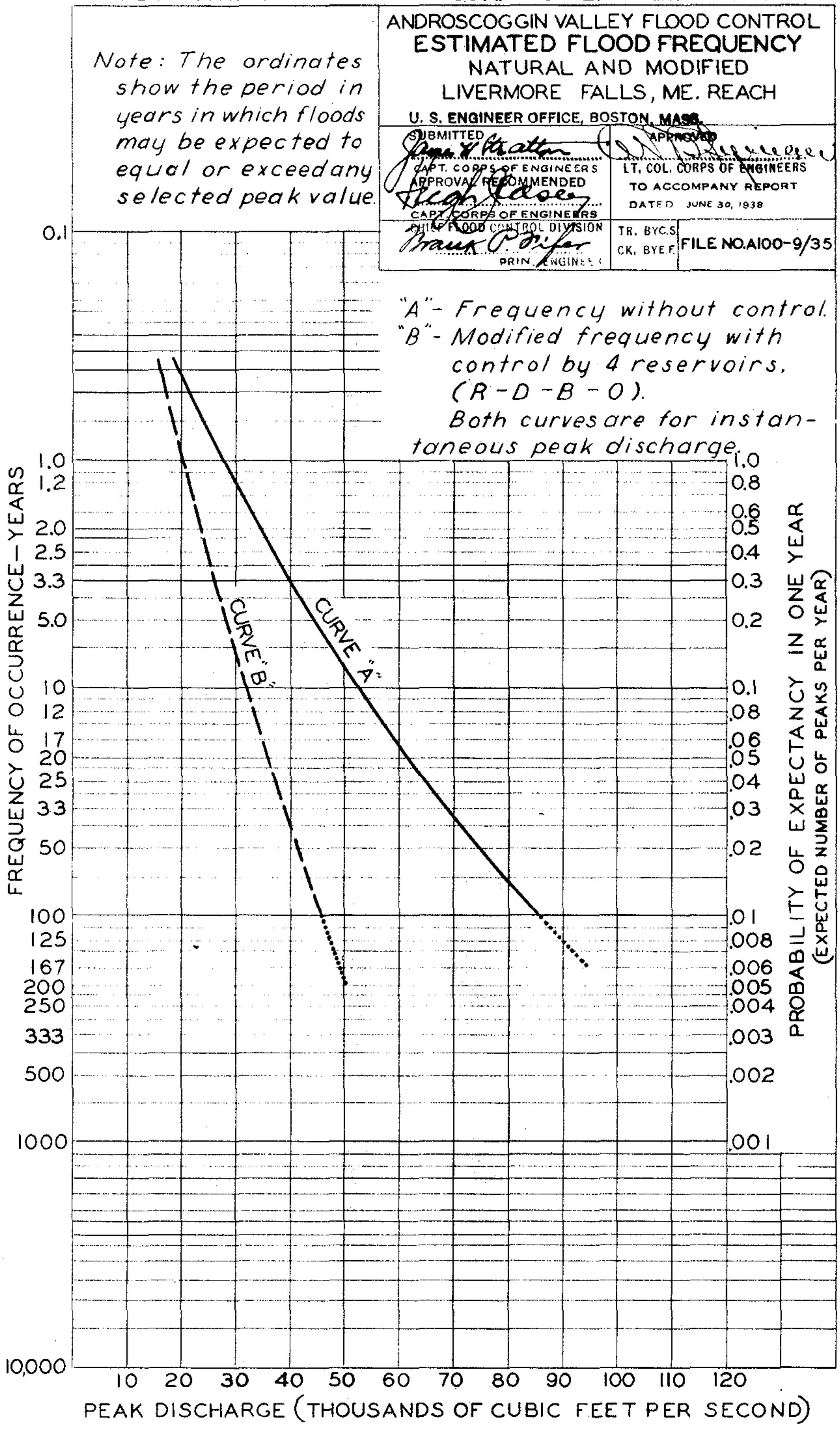
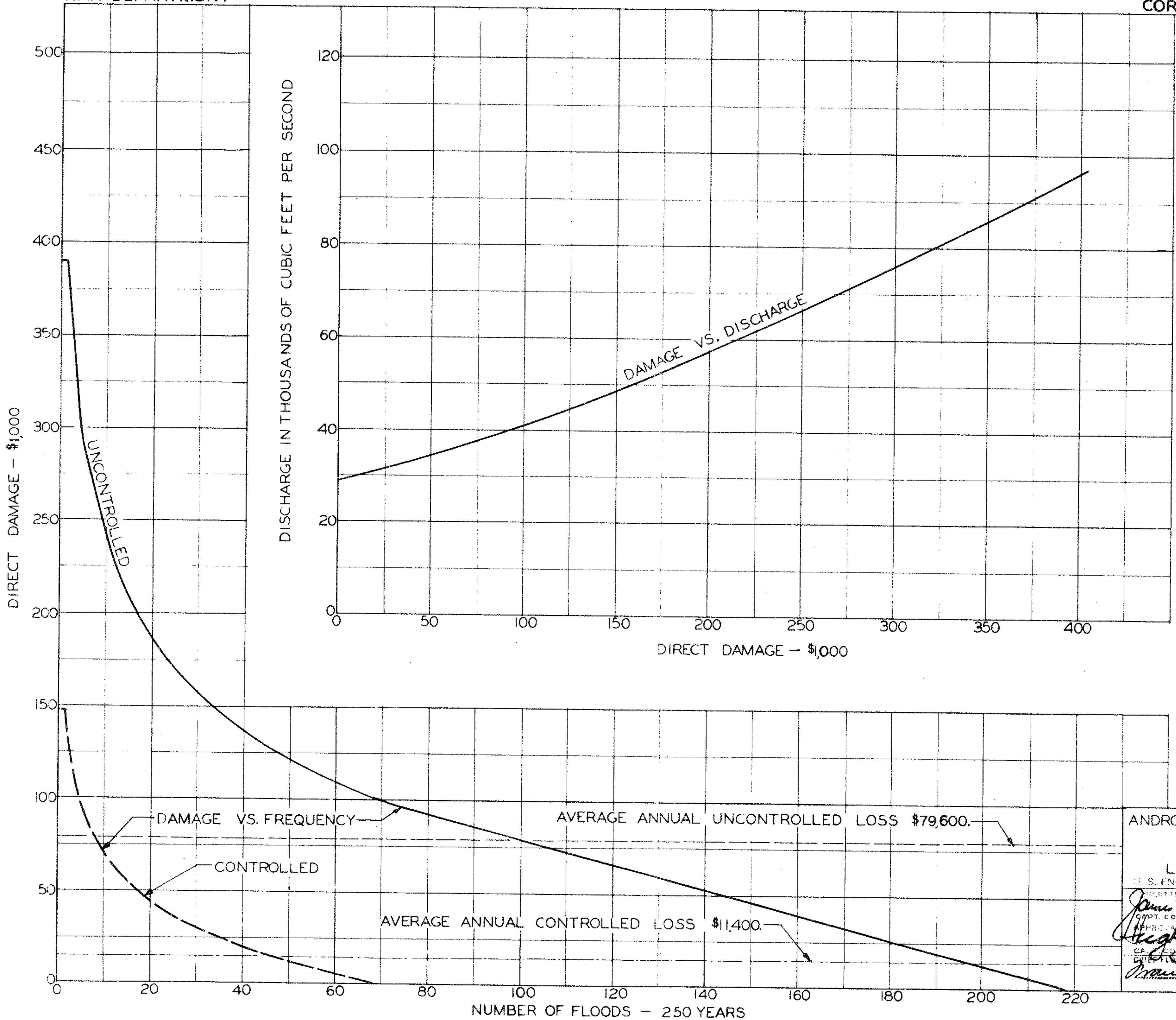


FIGURE 35



Note:
Modified damage-frequency curve is based on control by 4 reservoirs. (R-D-B-O).
Curves are based on direct damage only. Total annual loss, direct and indirect = 1.522 x direct.

ANDROSCOGGIN VALLEY FLOOD CONTROL
FLOOD DAMAGES
NATURAL AND MODIFIED
LIVERMORE FALLS, ME., REACH
U.S. ENGINEER OFFICE, BOSTON, MASS.

SUBMITTED: James H. Stratton, CAPT. CORPS OF ENGINEERS
APPROVED: LT. COL. CORPS OF ENGINEERS
APPROVAL RECOMMENDED: Hugh J. Casey, CAPT. CORPS OF ENGINEERS, CHIEF FLOOD CONTROL DIVISION
Frank P. ..., PRIN. ENGINEER
TO ACCOMPANY REPORT DATED JUNE 30, 1938
TR. BY W.Q.
CK. BY E.F.
FILE NO. A100-9/36

FIGURE 36

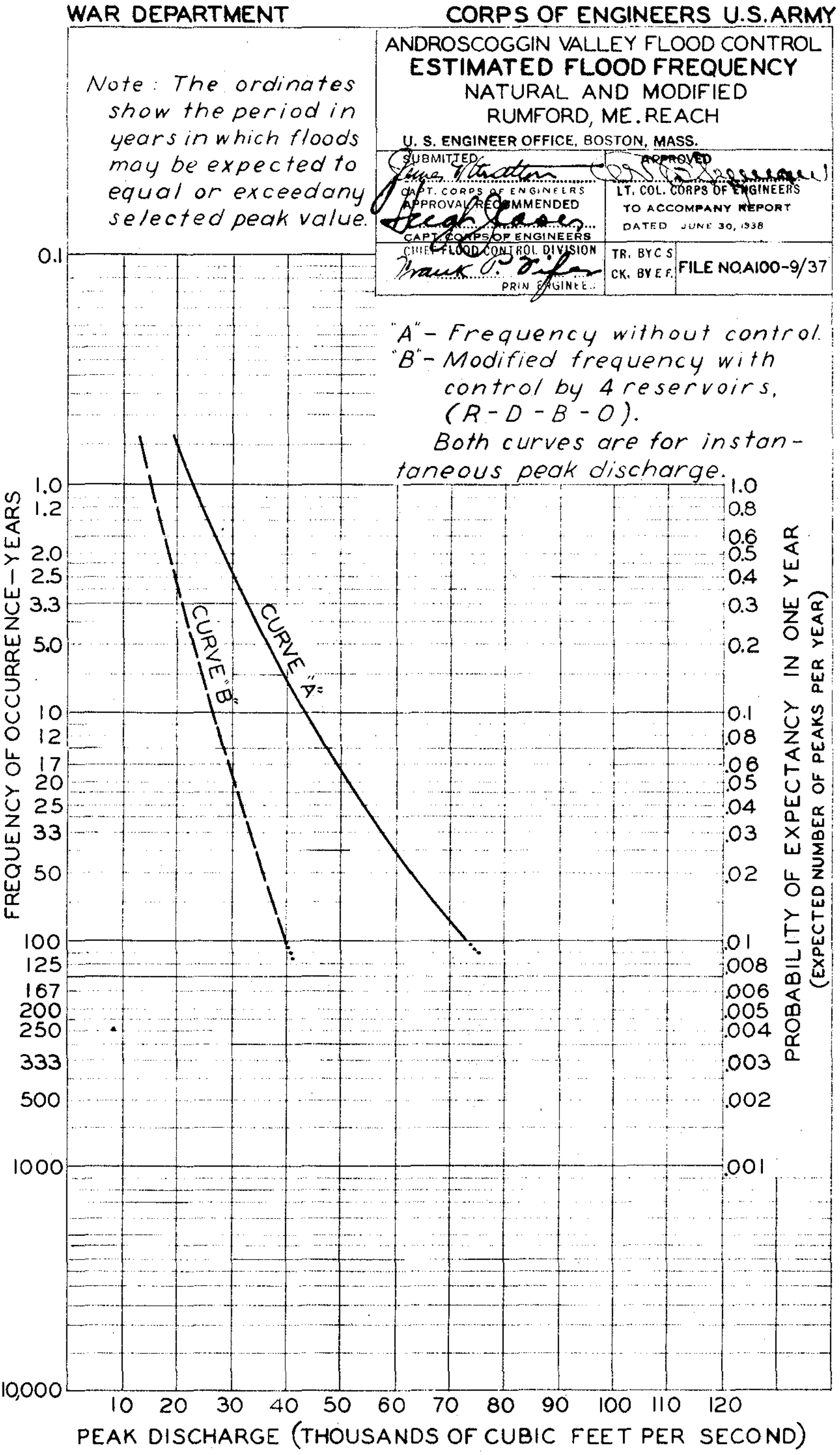
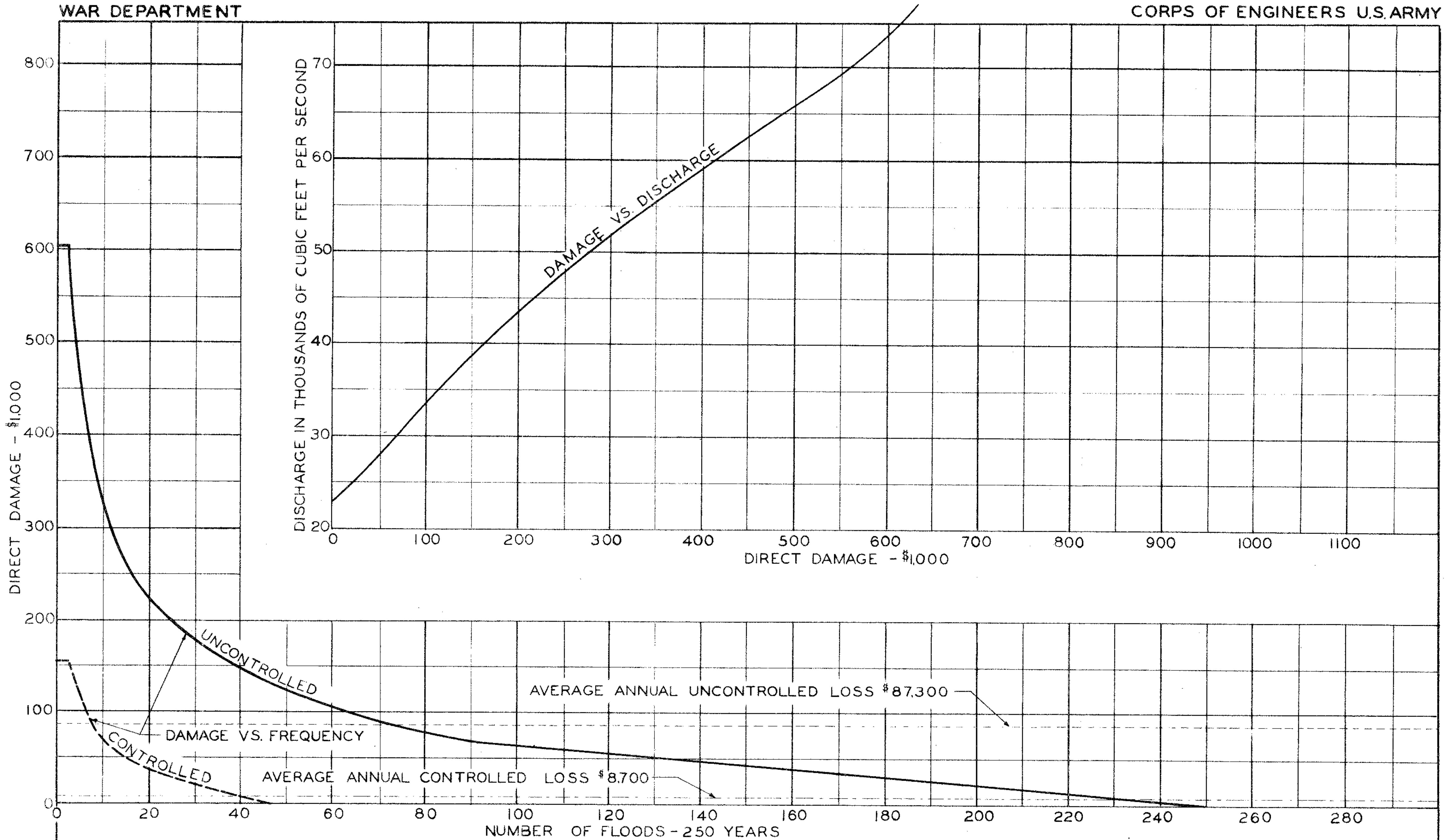

WAR DEPARTMENT
CORPS OF ENGINEERS U.S.ARMY
ANDROSCOGGIN VALLEY FLOOD CONTROL
ESTIMATED FLOOD FREQUENCY
NATURAL AND MODIFIED
RUMFORD, ME. REACH
U. S. ENGINEER OFFICE, BOSTON, MASS.
SUBMITTED
CAPT. CORPS OF ENGINEERS
APPROVAL RECOMMENDED
CAPT. CORPS OF ENGINEERS
CHIEF FLOOD CONTROL DIVISION
PRIN. ENGINEER
APPROVED
LT. COL. CORPS OF ENGINEERS
TO ACCOMPANY REPORT
DATED JUNE 30, 1938
TR. BY C S
CK. BY E F.
FILE NO. A100-9/37
Note: The ordinates show the period in years in which floods may be expected to equal or exceed any selected peak value.
"A" - Frequency without control.
"B" - Modified frequency with control by 4 reservoirs, (R - D - B - O).
Both curves are for instantaneous peak discharge.
CURVE "A"
CURVE "B"
FREQUENCY OF OCCURRENCE - YEARS
0.1
1.0
1.2
2.0
2.5
3.3
5.0
10
12
17
20
25
33
50
100
125
167
200
250
333
500
1000
10,000
PROBABILITY OF EXPECTANCY IN ONE YEAR
(EXPECTED NUMBER OF PEAKS PER YEAR)
1.0
0.8
0.6
0.5
0.4
0.3
0.2
0.1
.08
.06
.05
.04
.03
.02
.01
.008
.006
.005
.004
.003
.002
.001
10 20 30 40 50 60 70 80 90 100 110 120
PEAK DISCHARGE (THOUSANDS OF CUBIC FEET PER SECOND)

FIGURE 37

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY



Note:

Modified damage-frequency curve is based on control by 4 reservoirs, (R-D-B-O).

Curves are based on direct damage only. Total annual loss, direct and indirect = 1.946 x direct.

ANDROSCOGGIN VALLEY FLOOD CONTROL

FLOOD DAMAGES

NATURAL AND MODIFIED

RUMFORD, ME., REACH

U. S. ENGINEER OFFICE, BOSTON, MASS.

SUBMITTED

CAPT. CORPS OF ENGINEERS

APPROVAL RECOMMENDED

CAPT. CORPS OF ENGINEERS
CHIEF FLOOD CONTROL DIVISION

PRIN. ENGINEER

APPROVED

LT. COL. CORPS OF ENGINEERS

TO ACCOMPANY REPORT
DATED JUNE 30, 1938

TR. BY M.J.
CK. BY E.F.

FILE NO. A100-9/38

FIGURE 38

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY

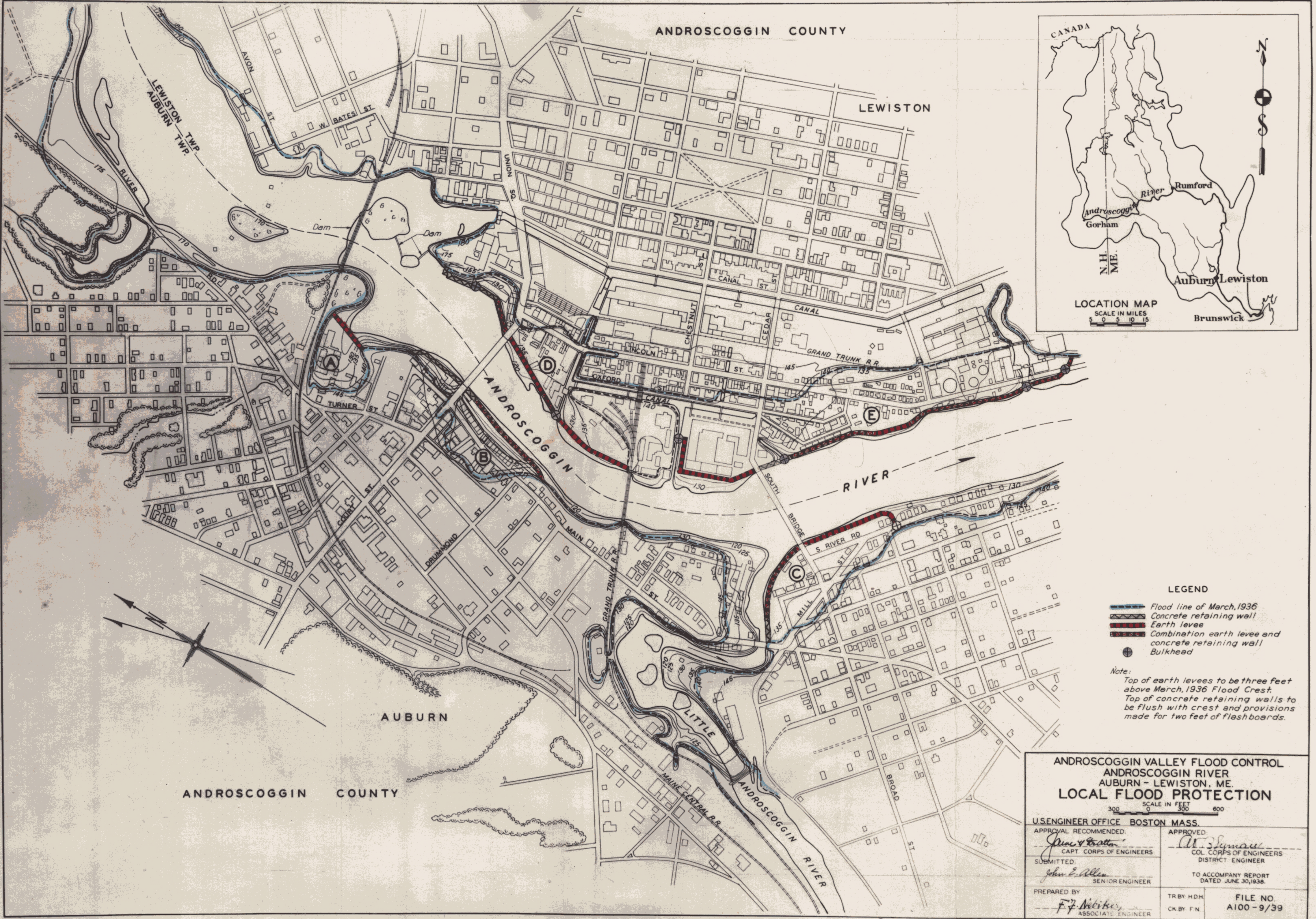


FIGURE 39

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY

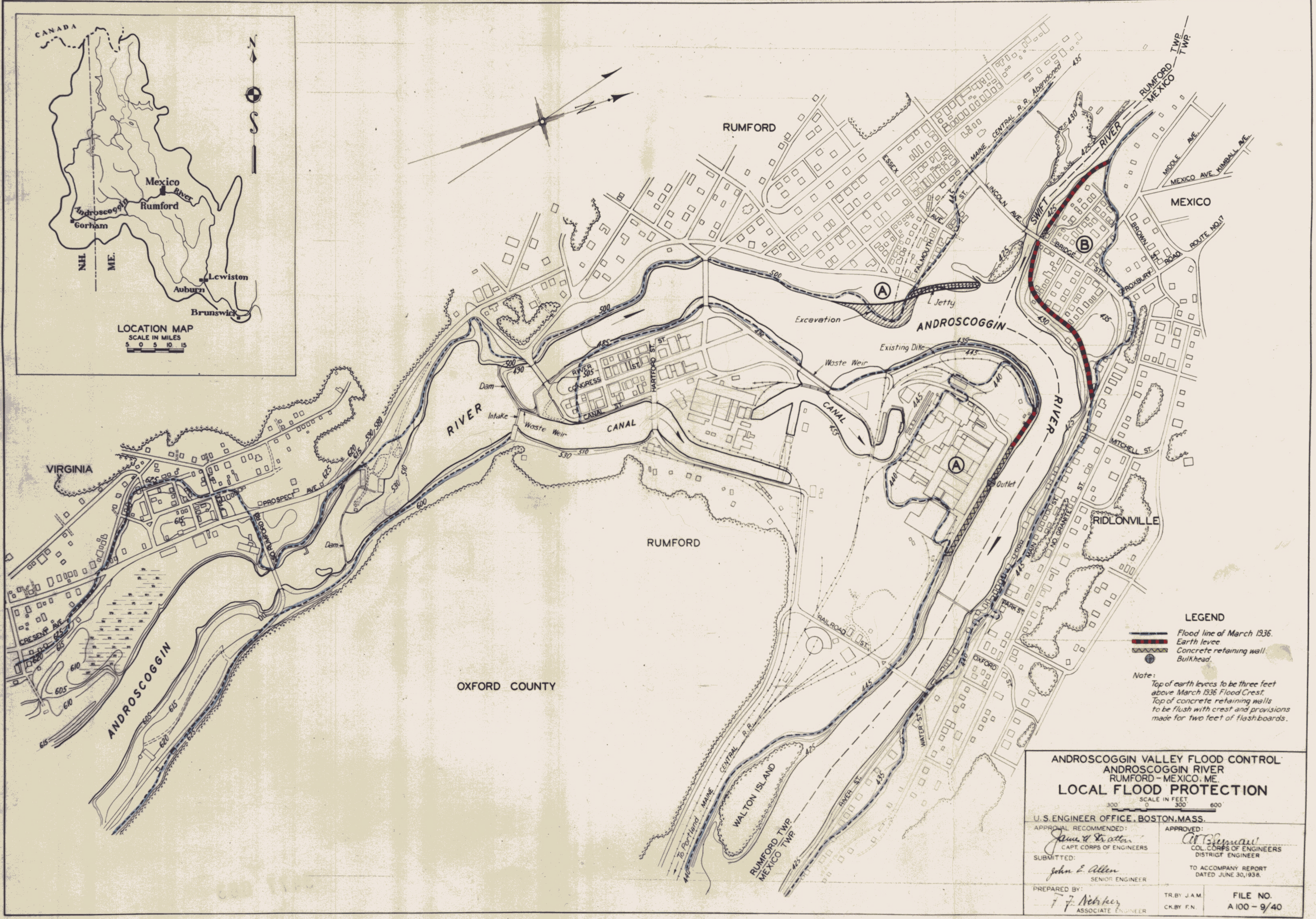


FIGURE 40